final report

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External evaluation of tedera proposal

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External evaluation of tedera proposal

Recommendations

1. There is a project steering committee which also includes additional livestock production expertise for a range of pasture regions where tedera is most likely to be adopted across southern Australia.

2. The proposed work should focus on animal (meat and wool) production studies over at least two years, at one (Mt Barker, WA) or preferably two locations and include animals that have a high growth potential, such as prime lambs. Key measurements should include, intake, animal growth rates and body condition and plant growth rates and nutritive value. These studies should have priority over detailed studies on animal reproduction. If these show worthwhile benefits then extend animal grazing trials to other sites.

3. The seed increase which is needed for the grazing trial needs to be done but the proposed costs of this need to be questioned.

4. There is to be a comprehensive review after two years to establish whether or not tedera is likely to be a commercially viable pasture. This will depend on
i). Animal grazing studies showing economic live weight gains/ha over summer and autumn in comparison with other feed sources.
ii). Obtaining higher average seed yields and developing efficient seed harvesting systems so seed costs are less than $100/ha.

5. Research on the adaptation, growth and persistence of tedera under grazing as a permanent pasture to be predominantly in the 400-600 mm rainfall zone on the less arable lighter textured soils of southern Australia, principally in WA.

6. Maintain and monitor some existing trials to collect evidence on long term persistence of tedera under grazing.

7. MLA funded research on herbicide tolerance and the assessment of herbicide residues should not proceed until there is a much clearer picture of the whether or not tedera will be commercially viable. If progressed, this research component should be managed by a steering committee which includes expertise in the registration of herbicides.

8. Research on increasing the harvested seed yields of tedera through plant breeding, improved agronomy and specialised harvesting techniques (funded by FFI CRC and RIRDC) is a high priority in the overall program.

Executive summary

A large collaborative project submitted MLA to develop the perennial legume tedera to fill the summer/autumn feed gap has been reviewed by an external panel for suitability for funding.
The review panel concluded that the benefits of tedera for increasing livestock returns during summer and autumn must be clearly demonstrated before there is substantial research on other aspects, such as seeding agronomy, plant adaptation and grazing systems.
The panel also concluded that the likely uptake of tedera by producers will be much less than claimed by the project proponents because of
1). The likely high cost of seed (over $100/ha).
2). Competition for pastures by existing species, such as lucerne.
3). Competition for land use by cropping in most regions.
The panel considered that the most likely economic fit for tedera is in the lighter textured soils in the 400 to 600mm zones. The uptake of tedera is also more likely to be greater in Western Australia than elsewhere.

The proposed research program has many components. These have been ranked into two priority groups. We recommend that only those components with priority 1 are funded initially. The priority 2 components should be funded only if results of the first phase indicate that tedera is likely to be a commercially viable business for seed growers and livestock producers. This assessment should also include outcomes of the RIRDC funded program on seed production.
Priority 1 components are
1). Seed increase for grazing trials.
2). A detailed sheep and lamb production trial in WA.
3). Plant production to be assessed in this grazing trial.
4). Nutritive value of tedera.
Concerns about palatability also need to be addressed in this first phase.

Priority 2 components include production agronomy and extensive grazing trials in Victoria and NSW as well as WA.

The review panel considers that the research team has good scientific skills in some areas, and is already very familiar with tedera research. They are strong in plant breeding but their expertise is not as strong in agronomy and seed production. They also need more expertise in practical animal nutrition and animal husbandry. We recommend that there is additional expertise in practical animal production research on a steering committee for this program. There also needs to be more involvement of the broader livestock industry.
There are concerns about the ability of the research leaders to manage a large multi-skilled project across a large geographic area if the proposed second phase of the project proceeds.

A case is presented to support further development and promotion of pasture species currently available commercially.

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Background

Tedera (*Bituminaria bituminosa var albomarginata*) was selected as one of the most productive and persistent species from extensive field trials across southern Australia during 2005 to 2008. One of the outstanding features of tedera was its retention of green leaves and general drought tolerance compared with the industry standard perennial legume, lucerne.
A large research group, lead by Dr. Daniel Real, DAFWA, submitted a project proposal to MLA to assess
1. The adaptation and agronomic management of tedera across a range of environments in southern Australia.
2. The production of adult sheep and lambs, including grazing management and any animal health issues, grazing tedera.
3. The type of farming systems where tedera is likely to be profitable and sustainable for growers.

Data from this program will also be used for more detailed cost-benefit analyses (using the MIDAS model) and for biophysical modeling using GrassGro.

The proposed project term is from 2011 to 2014 and the total budget request is $3,328,023.

Previous or current research on tedera in Australia includes
1. Evaluation of the production and persistence of tedera at 10 sites (2 in NSW, 2 in Victoria and 2 in WA) relative to other pasture genera over 3 years.
2. The mechanisms of drought tolerance of tedera by Mr. K Foster (PhD studies, DAFWA & UWA).
3. Plant density studies by Dr M. Ryan (UWA)
4. Plant breeding, including anther culture by Dr Real (DAFWA), and Drs J. Croser and M Castello (UWA).
5. Plant nutritive content by Dr J. Milton.
6. Animal production studies by Dr. C Oldham
7. Production of furanocoumarins and any animal health issues, such as photosensitization by……..
8. Herbicide tolerance screening by Mr. J Moore (DAFWA).
9. Seed production systems (funded by RIRDC to April 2013) by Dr D Real, in collaboration with Seednet (previously AWB Seeds) and Landmark.
10. Modelling the value of tedera in farming systems by Dr J. Finlayson.

As well, Dr. Real has good research links in Spain and Italy. The links are principally with plant breeders.
Collaboration between the DAFWA and other research groups in Australia and elsewhere has been very good.

Review objectives

The key objective is to review the DAFWA tedera proposal to MLA, including an assessment of:

- the technical data supporting the application
- commercial opportunities with tedera
- the key traits in tedera being developed
- recommendations / modifications to the proposal
- recommendations on priority for funding this or related /alternate initiatives.

Also, the assumed on-farm benefits and costs that would be required as input into a benefit-cost analysis are to be documented.

Key tasks included:

1) A review of the supporting documents to the MLA proposal including the FFI CRC breeding project, RIRDC seed project and nutritive value studies undertaken by DAFWA. Background documentation will be collated and provided by the researchers.
2) Meeting the project proponents in WA to confirm / develop the desk top findings on R&D gaps and opportunities. This should include understanding the opportunity to improve plant attributes required in livestock production.
3) Describing alternative opportunities that could address the opportunity stated for tedera and state why (strengths / weaknesses) they may be more appropriate or not.
4) Identifying and quantifying the animal production opportunities and natural resource management that could be realised from tedera.
5) Identifying the commercial opportunities and impediments that would need to be addressed to assist commercialization. This would include a wide range of topics from size of the target market and adaptation zone, seed production capability of tedera, market niche / need, potential skills required in the producers (eg need for rotational grazing).
6) Identifying the most likely target zones for tedera.
7) Identifying the on farm cost and benefits – suitable for incorporation into a benefit / cost analysis.
8) Making recommendations on the appropriateness of component project areas, or alternative component projects that may be required.
9) Making a recommendation on the merit and likelihood of success of the proposed project and related tedera projects.
10) Identification of other forage programs / opportunities that may deliver on the same outcome

A summary of answers from the literature and from discussions with researchers to review questions listed in the tender contract are listed in Appendix I.

Historical work in this review includes:

- FFI CRC germplasm evaluation and breeding program for tedera
- RIRDC seed production research
- DAFWA study of tedera's nutritive value for sheep
- DAFWA study of tedera's affect on the health of grazing sheep
- DAFWA whole farm MIDAS modelling

Methodology

The review panel consisted of
Dr Allan Mayfield, farming systems agronomist (SA) and panel leader
Ms San Jolly, animal nutrition specialist
Dr Kevin Reed, perennial pasture specialist
Mr Mike Krause, agricultural economist and modelling specialist
Dr Harm van Rees, farming systems agronomist (Victoria)
Mr Geoff Fosbery, farming systems agronomist (WA)

Three of the panel (Allan Mayfield, San Jolly & Kevin Reed) met with key research staff in Western Australia from the 29th to 31st of March, 2011.
This included a comprehensive seminar program on research to date on tedera.
It also included visits to DAFWA's field trial sites at Medina (near Perth) and at Mt Barker.
As well Geoff Fosbery inspected the trial site at Buntine, WA, Kevin Reed the site at Hamilton and Harm van Rees the site at Bealiba, Victoria.
In compiling respective sections of this report panel members also consulted widely with the industry (see Appendix III).

Results

A. Program organisation and leadership

The research team has good scientific skills in some areas, and is already very familiar with tedera research. They are strong in plant breeding with good links with researchers in Spain and Italy. But their expertise is not as strong in agronomy and seed production. They also need more expertise in practical animal nutrition and animal husbandry.

We recommend that there is additional expertise in practical animal production research in this program. There also needs to be more involvement of the broader livestock industry.

There are some concerns about their ability to manage a large multi-skilled project across a large geographic area.

The specifics of the project proposal to MLA are discussed in more detail in section F.

We recommend that there is a project steering committee which also includes additional livestock production expertise for a range of pasture regions where tedera is most likely to be adopted across southern Australia.

B. Plant production

1. Plant breeding & selection

The plant breeding plan approved by the FFI CRC appears well designed and is soundly based as to genetic resources, up-to-date technologies, appropriate organisational linkages and personnel. The list of breeding objectives is comprehensive - as might be expected with a mainstream species: field fitness (drought tolerance, summer leaf retention, summer-autumn growth, persistence and grazing tolerance), secondary compounds, seed production, water logging tolerance, salinity tolerance, cold tolerance and (unspecified) insect and disease resistance and tolerance.

They have a large range of plant genotypes for characteristics such as plant growth habit, dry matter production, flowering dates and durations and seed yields. Daniel Real is a world leader in tedera breeding. Research by UWA researchers has enabled two generations of tedera to be grown per year using tissue culture systems.

2. Seeding and seedling establishment

Preliminary studies (by Megan Ryan, UWA and others) on establishing tedera have found

i). The minimum plant density for maximum dry matter production is between 8 and 16 plants/square metre.

ii). Seed has a high dormancy for 3 months after harvest but after then has a high germination % (approx. 80%).

iii). Seed is tolerant of a range of seeding depths (from 2cm to 10cm in sand).
iv). Seeding rate for 12 plants/square metre and 25mg seed weight would be 5kg/ha with a germination of 80% and establishment of 70%.

Further research on establishment still required includes
i). Seeding rates and row widths for maximum seed production.
ii). Impact of root rot fungi on seedling establishment and the control of any root rots with fungicides.

The relative large seed size (approx. half the size of a wheat seed) and tolerance to a large range of seeding depths means that commercially tedera could be sown with standard grower seeding equipment.

3. Weed control

Young stands of tedera do not compete well with weeds and, hence, effective herbicides for likely weed problems are essential for not only commercial seed production and pastures but also for field trials.
There are several examples where field trials were poor, or lost altogether, due to infestation of common weeds.
These include the animal grazing and herbicide screening trials at Mt. Barker where there were thick infestations of toadrush. As well, in a species evaluation trial at Hamilton, tedera was overgrown with weeds during the winter.

Of the commercial selective herbicides currently available only one (Broadstrike® (flumetsulam)) has a broad registration for “pastures”. Two others (paraquat and Reglone® (diquat)) also have a registration for ”pastures” but are essentially non-selective desiccant herbicides. The rest of the potentially useful herbicides are registered specifically for a pasture type, such as “lucerne” or “clover”.

Preliminary work by John Moore (DAFWA) and Megan Ryan (UWA) indicate that tedera has similar tolerance as lucerne to herbicides applied to young plants.

Much more testing is necessary to establish
a). The full range of herbicides that can be safely used on tedera.
b). The tolerance of tedera to these herbicides applied at a range of growth stages.
c). The tolerance of tedera to these herbicides growing in different soil types and conditions.
d). Herbicide options for control of tedera.
e). Data packages for the registration of these herbicides on tedera.

A student project on herbicide testing on seedlings in pots at UWA this year will provide a useful guide on which selective herbicides can be used on tedera and maybe sufficient to recommend suitable herbicides for weed control in grazing

trials. The more detailed herbicide trials planned in this proposal are not a critical requirement at the initial stages of this program.
When the herbicide field research is being done for product registration it is critical that it meets the requirements for APVMA and the chemical industry. This includes the chemical residue studies, which need to be done according to quality assured GLP procedures. The research team also needs to establish whether or not any previous studies on chemical residues in animals are required or whether studies with these chemicals on other similar pasture species, such as lucerne, are sufficient. It is also important that the chemical companies be involved, especially if any of the chemicals are proprietary products.

Field trials to collect data for herbicide residue analyses should not proceed until there is a much clearer picture of the whether or not tedera will be commercially viable.
The MLA component of herbicide research should be managed by a steering committee. They should meet twice each year. The first meeting is to review progress and to plan for the coming year and the second meeting to inspect field experiments.
This steering committee should include a person familiar with herbicide registration processes, such as Mr Kevin Bodnarak (AKC Consulting). This group needs to ensure that their research and development plan meets the registration requirements and that there is sufficient budget for this.

4. Plant nutrition and nitrogen fixation
Tedera appears tolerant to a wide range of soil pH and textures but appears not to have a high level of tolerance to salinity or subsoil aluminium. Otherwise, it does not appear to have any particular sensitivity to nutrient deficiency or toxicity compared with other pasture species, such as lucerne.
The research group has identified a specific rhizobium for tedera which nodulates root systems effectively.
It appears to be no more tolerant of waterlogging than lucerne in the few comparisons done so far

5. Plant growth rates and drought tolerance
There have been some measurements of dry matter production in field trials over several sites and years in WA. At these and other trials at Mt Barker assessments (see p20) have been made of total dry matter production at different times of the year but not of growth rates *per se*. There is also insufficient site x accession data.

Detailed plant physiology studies (by Kevin Foster, DAFWA) show that the observed drought tolerance of tedera, relative to other perennial pastures, such

as lucerne, is due to many different mechanisms, from leaf rolling, osmotic adjustment and an overall high water use efficiency.
A valuable feature of tedera is its far greater retention of leaves, compared with lucerne when under moisture stress.

6. Seed production

Seed yield is a limitation of current research projects and is likely to be a major limitation in the commercialisation of tedera. Repeated hand harvesting of irrigated tedera lines has given seed yields ranging from 50 to 400kg/ha (Fig 1). There were large differences between tedera lines and so there is potential to select lines with higher seed yields.

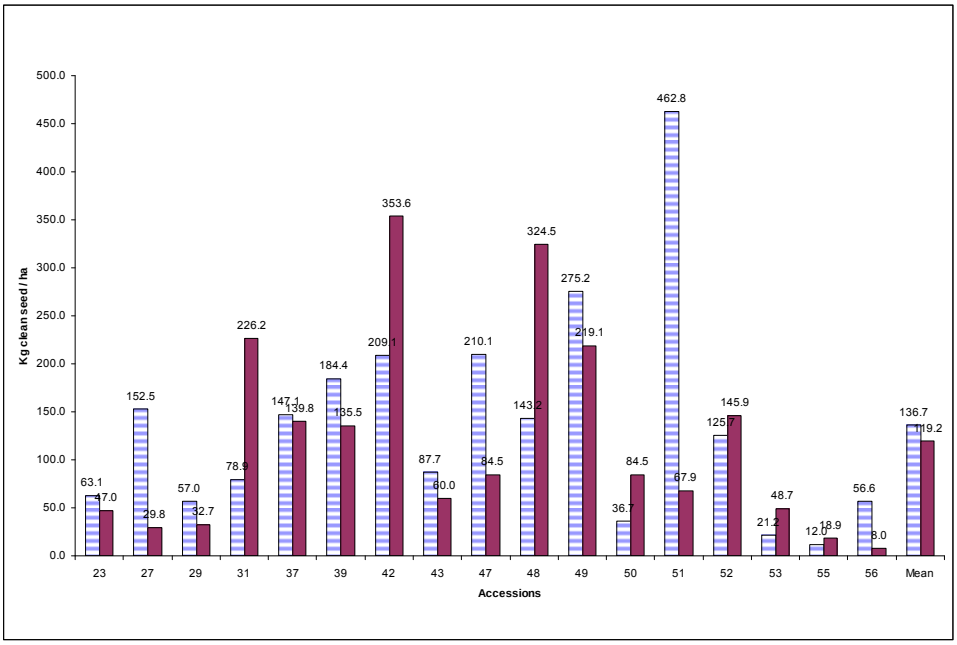

Figure 1. Seed production (kg/ha) from up to 4 successive hand harvests from irrigated tedera lines. Values are the mean of two years (2009 and 2010).

Because of these low yields there is only limited seed for larger field trials, such as the proposed grazing trials.
Low seed yields will also mean a likely high cost of commercial seed which will be an impediment to the uptake of tedera. The seed cost for other species with relatively low seed yields, such as sulla, is $20/kg (Table1). Using a sowing rate of 5kg/ha (based on a seed weight of 25mg and sowing rate of 12 seeds/square metre) the seed cost is likely to be at least $100/ha. Seed industry personnel consider that this cost will be a major limitation to the uptake of tedera, especially in the more opportunistic situations in essentially cropping enterprises in medium to lower rainfall regions.

Table 1. Seed yield and retail price for seed of some perennial pasture plants.

Perennial pasture species	Seed yield (kg/ha)	Retail price# ($/kg)	Seeding rate (kg/ha)	Seed cost $/ha
Tedera	50-400	?	5-10	
Lotus corniculatus	50-400	50* when withdrawn from market in 2010**	6-10	$300 - $500
Greater *Lotus*	20-150	50* when withdrawn in 2005**	2-4	$100 - $200
Caucasian clover	100-500	withdrawn	1-4	
Sulla, cv Flinders	100-500	19	3-8	$57 - $152
Lucerne	250-800	6-15	2-10	$12 - $150
White clover	500-1000	7-15	1-2	$7 - $30
Ryegrass	800-2000	4-10	7-10	$28 - $100
Phalaris	500-800	16-17	1-3	$16 - $51
Tall fescue	800-2000	12-14	10-20	$120 - $280
Cocksfoot	250-650	11-12	2-3	$22 - $36
Kangaroo grass	?	1200	4	$4,800
Microlaena	?	110-180	15	$1,650 - $2,700
Wallaby grass	?	75***-180	2	$150 - $360

* was ~$20/kg in coated forms which contained (varied with company) ~50% seed

** unavailable in NZ, Europe and US also as at 2011 *** pelletized form

based on advice from seed company representatives, including AusWest Seeds, PGG-Wrightson Seeds, Specialty Seeds, Stephen Pasture Seeds, Seed Distributors, Global Pasture Consultants, Native Seeds, Pasture Wise.

With high seed costs, the risk of tedera establishing as a weed in crops on mixed farming properties and possible concerns with trafficability, soil moisture depletion and the possible desirability of rotational grazing, tedera may not be embraced as a pasture break in phase farming systems. The provision of tedera as a permanent pasture to extend the season over which fast growth rates can be expected for prime stock would seem the more relevant concept. The higher rainfall districts with their higher carrying capacity are more likely to employ tedera; with relatively high per ha margins they will recoup its establishment cost sooner.

Research on increasing the harvested seed yields of tedera through plant breeding, improved agronomy and specialised harvesting techniques (funded by FFI CRC and RIRDC) is a high priority in the overall program.

The FFI CRC is funding further plant breeding and RIRDC is funding evaluation of higher yielding lines and also seed harvesting technologies. The RIRDC project (PRJ3760) has been extended by a year to April 2013 because of a plant establishment failure in the first year.
This RIRDC project also has strong links with the seed industry (Seednet, Landmark and seed growers) which will increase the likelihood of a practical outcome. The role of Landmark and Seednet in agronomic and seed production field work has not been clearly defined. It is expected that they will develop field trial programs for further agronomic research and promotion as they see the need.

Tedera will be the only pasture species that Seednet will market – the other varieties they currently market are for broadacre cropping. There is a risk that the value of tedera to growers will be ”oversold” by enthusiastic agronomists promoting it for situations where it may not succeed. This may then cause a reaction by growers and resistance to further uptake of tedera.

We note that agronomy for seed production is not specified in the RIRDC project. It is important that aspects including optimum plant spacings, irrigation, grazing times are tested to obtain the maximum seed production.

7. Production limitations due to insects

Tedera appears tolerant of common insect pests, such as red legged earthmite and lucerne flea, that affect other pasture legumes.
There is a report of damage from mealy bug in North Africa (Neil Ballard, pers. comm.) and scale insects (*Icerya purchasi*) in the Canary Islands but not in Australia. There is a possibility, however, that mealy bugs present in Australia could damage tedera pastures.
One potential insect pest that is relatively easy to control in southern Australia is native budworm in seed crops.
The research group needs to establish whether or not chemical registrations already exist for likely pests in pasture legumes. If not, then they need to include research trials or other data equivalence for registration in their program.

8. Production limitations due to diseases

The leaves of tedera we inspected were relatively free of any foliar diseases whereas lucerne stands can have significant levels of diseases.
This may be because tedera is not yet widely grown, although the general evidence is that it is relatively resistant to leaf and stem diseases.

There were instances of a mycoplasma-like disease in tedera at Medina, WA, similar to what can occur in lucerne. As well, tedera was stunted by root knot nematodes in another sowing block at Medina.
Tedera may also be susceptible to root rots, such as rhizoctonia, at both the seedling and adult plant stages. There are instances of poor establishment in field trials, especially in wetter areas, such as Mt, Barker. This should be investigated further and, if necessary, a seed treatment with fungicide (such as metalaxyl) be used in field trials and seed production areas.

9. Persistence

Tedera has continued to persist at field sites sown in 2005 and 2006 in WA. The actual extent of persistence is not clear as there have been no recent measurements of plant numbers. It can however survive adverse conditions, including severe droughts (in WA) (Figure 2), being grazed to the ground by locusts (at Bealiba) and rabbits (at Merredin) and being overgrown with weeds (at Hamilton).
Tedera will also regenerate from seed. Regenerated plants were common at both the Medina and Mt Barker trial sites.
It is not considered however to be a weed threat. Before importation and field trails in Australia there was a thorough review of its weediness risk.

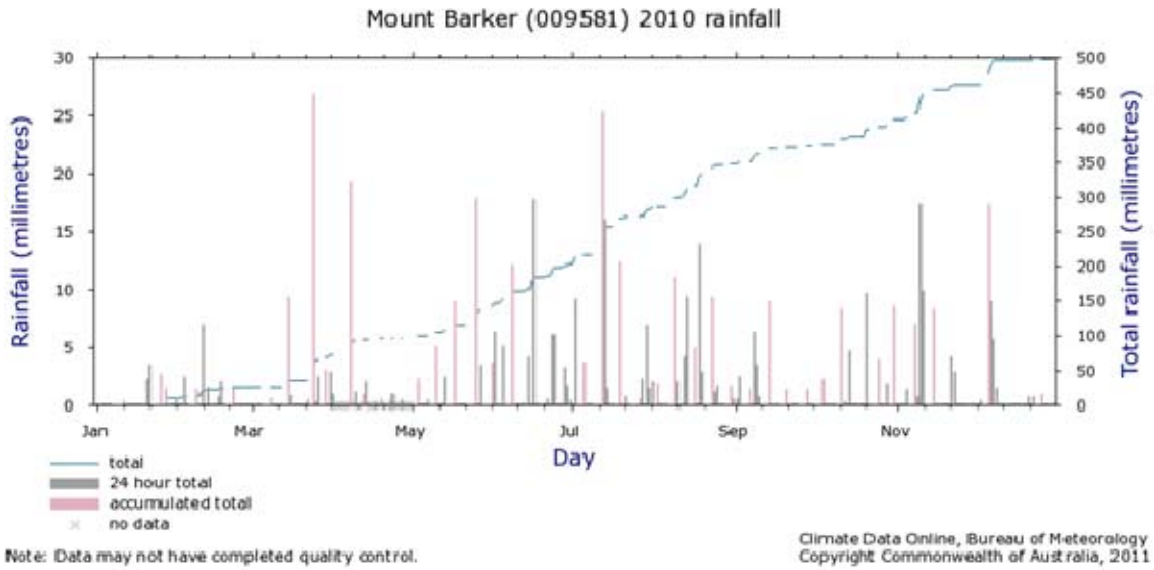

Figure 2. Daily and cumulative rainfall, Mt Barker, 2010.

10. Regional adaptation

The trials so far in Australia and observations in the Mediterranean region indicate that tedera has relatively wide adaptation. But there are still many areas in southern Australia where it has not been tested at all or very little, such as the

SA & Victorian Mallee and the northern sandplains in WA. There are no areas tested so far where it definitely will not grow, although it appears not to be tolerant to waterlogging or salinity.

C. Plant nutritive value and animal production

1. Nutritive value for livestock

There is a scarce amount of published nutritive value data on tedera, especially across seasons and environments. The comments below are made about all samples found in the literature as well as from data provided by DAFWA for the purposes of this review.

i). Crude protein

The crude protein of tedera varied from 10.3% to 21.3% in paddock samples and from 14.2% to 17.7% in pot samples that were leaf dominant.

Of all leaf and stem samples analysed (attached pdf file) the range in crude protein values included:

a). Autumn: 12.9% to 21.3%
b). Spring: 12.4% to 21.2
c). Summer: 9.4% to 17.1%
d). Winter: 17.6% to 20.2%

ii). Neutral detergent fibre (NDF)

NDF ranged from 53.7% to 45.9% in samples taken in Italy during summer.

Autumn harvested pot trial and plot samples from WA ranged from 27.4% to 34.6%. Samples of leaf and stem taken in WA during spring ranged from 30.6% to 42.9%. Samples taken in summer in WA and Italy varied between 35.5% and 42%. No NDF analyses have been published on plant material sampled in winter.

iii). Acid detergent fibre (ADF)

Tedera sampled in summer in Italy and Spain varied in ADF from 36.9% to 39.5%. Accessions 3, 5, 6 and 9 sampled in spring 2010 varied in ADF from 19% to 20.3%. Italian samples of tedera analysed in summer ranged from 37.3% to 41.9%. The ADF of samples taken in WA in autumn ranged from 26.8% to 53.9%. One sample taken from the Buntine site in WA in summer had an ADF of 28.6%. The ADF of one winter sample was reported as 21.9%.

iv). Ash content

The ash (mineral) content of tedera is similar to that of pasture grasses (+/-9%).

v). Digestibility and estimated metabolisable energy (ME – MJ ME/kg DM)

ME appears to have been calculated from DOMD using the equation (DOMD x 0.230) -3.001. Estimated ME ranged from 7.25 – 13.4 MJ ME/kg DM.

The majority of the samples with ME > 12 were analysed from cuts taken in September, 2010 at the Mt Barker, WA site.

Digestibility ranged from 52.3 to 69.2% in autumn cut samples however DOMD was not measured. ME of the autumn cut samples was estimated from DDM% using the calculation (DDM% x 0.17) - 2.0 in an attempt to derive an indicative ME value for autumn of tedera. On this basis the ME ranged from 6.9 to 9.8 MJ ME/kg DM. Winter ME values taken at Buntine, WA, were 9.4 (leaf) and 6.4 (stem) and at Newdegate, WA, 7.6 (leaf) and 3.9 (stem). ME values were at their peak in spring (12.5 to 13.4) followed by autumn (8.7 to 11.7) with do data available for summer and low ME's for winter (3.9 to 9.4).
The estimates of digestibility of 80% by Independent Laboratory Services (John Milton's laboratory) require verification as they are based on calibrations using non-tedera material.

vi). Water soluble carbohydrates (WSC)
WSC is indicative of the soluble plant sugars, a readily fermentable energy source for ruminants, and is often used as an indicator of palatability especially for the export hay industry. There is little evidence to support a link between WSC, preference and or palatability.
WSC was analysed in the tedera samples taken in September, 2010 and ranged from 9 to14%. These levels would meet the requirements of Grade 2 oaten hay which is suitable for domestic use only.
There is evidence of an accumulation of plant sugars being a drought tolerance mechanism (Pecetti *et al, 2007).*

vii). Dry matter production
To date there has been scant measurement or publication of dry matter production for tedera.
DM production measured twice a year in studies at Newdegate have measured a wide range of weights for different accessions and sowing densities:

a). November 2009 to March 2010: 400kg DM/ha to 3520kg DM/ha
b). March to November 2010: 1320kg DM/ha to 17.8t/ha

The highest dryland DM production was measured at this site in June 2007 where spring production was 3t DM/ha with a daily growth rate of 20kg DM/ha/day.
Over 12 months at Hamilton the highest yielding succession of tedera sown in November, 2009 was 1.8tDM/ha in March and 2.2 tDM/ha in May.

viii). Dry matter production – response to grazing
Current observations by researchers at the WA sites include an increase in DM production in response to grazing. No loss of dry matter production has been observed to date if tedera was left ungrazed (Ryan, 2010). Poor productivity has been observed under very dry conditions (<250mm annual rainfall - Ryan, 2010).
It is not yet known how tedera will tolerate overgrazing.

ix). Dry matter production compared with other species
It is clear that tedera retained significantly more leaf under dry conditions than lucerne or clover (Figures 2 & 3) at the Mt Barker trial site visited. However, it

should be noted that the lucerne variety sown in the comparative plots was SARDI 10 which is highly winter active. Comparing tedera with more summer active lucerne varieties may deliver a different result.

Figure 2. Tedera and lucerne (Mt Barker, March, 2010)

Figure 3. Tedera and lucerne (Mt Barker, November, 2010)

x). Mineral profile

The mineral profile of tedera, which was analysed in August 2010 (Agwest Laboratories) and September 2010 (Independent Lab Services, WA), was found to be comparable with that of lucerne. These samples were taken from the Mt Barker site where a deficiency of selenium was noted in August; however selenium was not analysed in September. The soil tests were not analysed for selenium and no alternative trial sites or species were analysed for minerals.

Therefore it is not clear if the selenium deficiency was site, season or species specific.
Two tedera accessions sampled at Mt Barker in September were below animal requirements for sulphur however the replicates of these samples were not deficient.

xi) Amino acid profile
The amino acid profile of tedera is similar to that of clover and lucerne in results of tests by Agwest Animal Health Laboratories.
Lysine and methionine were low which is typical of most ruminant diets.
No cost effective supplement for these amino acids has been developed for ruminants.

xii) Fatty acid profile
The fatty acid profile of 3.5% is similar to that of grasses (Table 2).

Table 2. Fatty acid profile of tedera compared with grasses.

	% composition total fatty acids	
	Tedera	Pasture grasses
C10:0	0.04	0.03
C12:0	0.11	0.15
C14:1	0.37	0.40
C14:1N5	0.16	0.04
C15:0	0.06	0.18
C16:1	12.99	13.46
C16:1n7	0.08	0.54
C17:0	0.17	0.11
C18:0	1.63	1.55
C18:1n9 cis & C18:1trans 9	0.25	1.32
C18:2n6 cis & C18:2 trans 9 12	11.59	14.31
C18:3n3	64.91	62.35
C20:0	0.29	0.60
C20:4n6	0.00	
C22:0	0.44	0.89
C20:5n3	0.06	
C24:0	0.95	0.62
C22:6n3	1.14	

xiii). Vitamin E profile (Agwest Animal Health Laboratories):
Tedera samples analysed from the Mt Barker site in August 2010 were found to have lower levels of Vitamin E content (37.8 to 85.7mg/kg DM) than the expected range for grasses (105-166mg/kg DM). These levels not sufficiently high to prevent a deficiency as they are significantly below daily requirements for all classes of sheep (NRC, 2007). However, the levels are more likely to meet the current daily requirements for grazing cattle of 15 to 60mgs/kg DM (SCARM, 1990; NRC 2000).

2. Plant growth rates and animal responses from grazing
From the data collected to date, plant growth rates (PGR) have been as follows:

a). November 2009 to March 2010 – PGR varied from 3.3kg DM/ha day to 29 kg DM/ha/day across all sites.

b). March 2010 to November 2010 – PGR varied from 5.4kg DM/ha/day to 73 kg DM ha/day.

It is assumed the level of 73kg DM/ha/day was representative of the irrigated site south of Perth. At Hamilton the maximum growth rate was 33 kg DM/ha/day in its first autumn.

There is still a large amount of variation in DM production in accessions of plant material, which continues as a component of the selection program.

As the intention of the breeding and selection program for this species in Australia is aimed at producing a plant species that fills the summer and autumn feed gap with high quality feed it would seem appropriate to calculate stocking rates for the period of December to April.

There was limited data available from animal production or grazing trials.
Grazing studies have been limited to date by the low level of seed production and ongoing selection of accessions that produce the highest amount of leaf material per plant.

A rotational grazing site has been established at Mt Barker, WA, in a 600 mm rainfall zone which is currently being managed by Dr Chris Oldham (Table 3). In December 2010 mature Merino wethers at 45kg LW were assigned to graze the plots of tedera. Feed on offer limited the trial to 14 days of grazing before the supply of tedera was depleted. There was 460kg DM /ha of tedera and 2400kg DM/ha of pasture available at the beginning of the trial period. A comparative grazing was undertaken on a neighbouring plot of subclover pasture with 3000kg DM/ha feed on offer pre-grazing.

Table 3. Sheep performance during grazing tedera (Oldham 2010, unpublished)

	Live weight change g/hd/day	Condition score change	Skin fold change	Skin colour change
Sub-clover	48	-0.1	1.2	-1.2
Tedera-3	246	0.3	2.0	-1.5
Tedera-5	208	0.1	1.6	-1.5
Tedera-6	270	0.1	1.5	-1.3
Tedera-9	192	0.2	1.7	-1.7

This was not intended as a grazing trial but was established to assess the risk of photosensitisation (PS) from grazing tedera. It is unclear if the exposure to tedera was sufficient to induce PS.

Although the grazing trial was not a performance trial and sheep were weighed immediately out of the paddock it was apparent that weight gain did occur. However, mature sheep do not "grow" as such and it remains to be seen as to how much of this weight gain was attributable to the total feed on offer or the 15% tedera component.

A metabolism study was conducted with mature Merino wethers where they were fed freshly cut tedera in bunches. The purpose of this work was to determine *in vivo* digestibility. Dry matter intake was compared with dry matter on offer and changes in liveweight were recorded however it was stated that there was a shortage of plant material that affected the trial. This is not supported by the available data (Figure 4a).

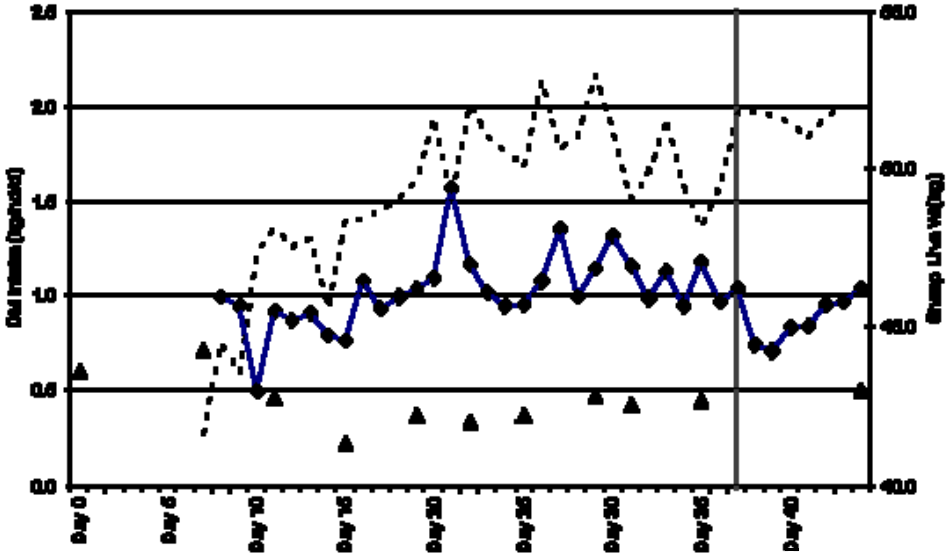

Figure 4a. Dry matter offered (…), eaten (♦) and liveweight (▲) of sheep fed Tedera (Oldham, 2010 unpublished).

Digestibility of the cut materials were not directly comparable: the lucerne was chaffed (finely cut stems and leaves) whereas the tedera was fed as bunches and the lower stem was left as residue.

Dry matter intake of the lucerne chaff was significantly higher than that of the tedera (Figure 4b). Also the trial was conducted in July when tedera appears to be less palatable. As tedera is not intended to fill winter feed gaps it may be more relevant to conduct these studies with tedera grown in summer and autumn.

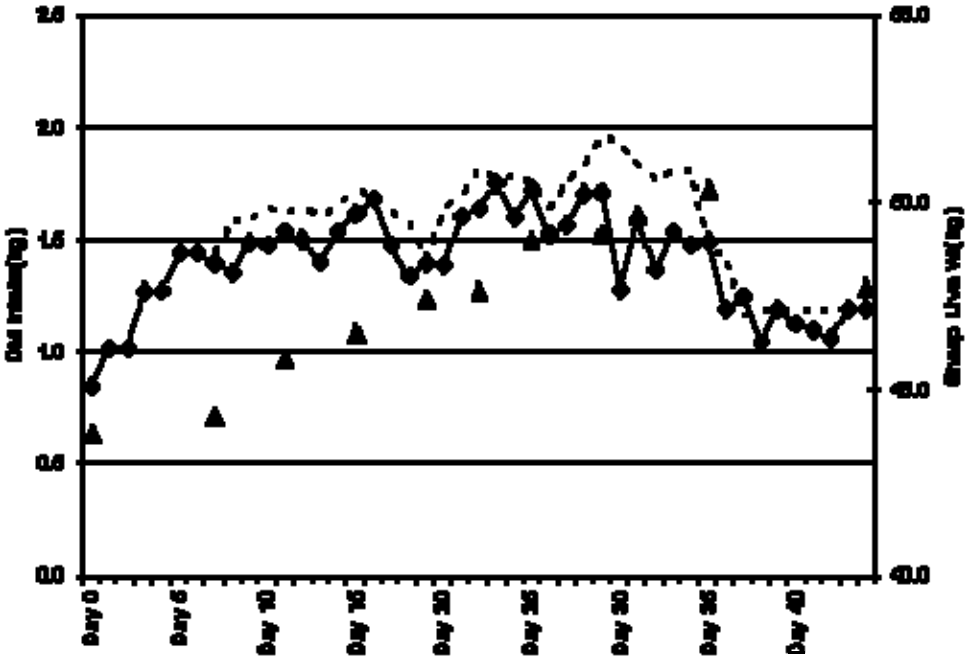

Figure 4b. Dry matter offered (…), eaten (♦) and liveweight (▲) of sheep fed lucerne chaff (Oldham, 2010 unpublished).

The proposed work should focus on animal (meat and wool) production studies over at least two years at one (Mt Barker, WA) or preferably two locations and include animals that have a high growth potential, such as prime lambs. Key measurements should include, intake, growth rates and body condition. These studies should have priority over detailed studies on animal reproduction. If these show worthwhile benefits then extend animal grazing trials to other sites.

These studies should also include measurements of plant production and palatability as well as any animal health issues, such as photosensitisation.

3. Preference and palatability

Resistance to grazing has been reported in the literature (Gutman *et al*, 2000; Pecetti *et al,* 2007) and has largely been attributed to secondary compounds found in young leaves.

In the short grazing trials (14 days) conducted at Mt Barker, WA in December, 2010, it was noted that there was a 4 day delay in mature merino wethers adapting to the tedera. However, there was also 2400kg DM/ha of sub-clover dominant inter-row pasture available with which the sheep would have been familiar.

Tedera appears to be less palatable in winter and spring than in summer and autumn. A difference in palatability between individual plants has been observed. The plants have a tea-like smell, but they are neither salty nor bitter to taste.

It is not clear if the issue is one of palatability of familiarity (neophobia). It is well recognised that drought tolerance in plant species is often associated with the presence of secondary compounds some which can cause animal health problems and which can also reduce voluntary intake.

4. Anti-nutritional factors

The presence of secondary compounds in tedera is worthy of further research due to the risk of photosensitisation. There remain questions about its palatability and whether this is a plant specific characteristic, a seasonal issue or an issue with the species in general.

If the species is to be used to support young growing lambs or calves, any reduction in voluntary intake or prolonged adaptation time need to be thoroughly investigated as a component of the research program.

There does not appear to be any reason why mineral or trace element deficiencies should be any more or less prevalent when grazing tedera than when grazing alternative pasture species; these issues are more likely to be site specific.

If tedera is significantly less palatable during winter, nitrate levels should be investigated as a potential cause due to the risk of nitrate toxicity and death.

It has been confirmed in WA studies that tedera contains two major furanocoumarins (angelicin & psoralin) which may have the potential to increase the risk of photosensitisation (PS). No PS has been reported in goats grazing tedera in the Canary Islands where tedera is common.

Furanocoumarins have predominantly been found on the leaf surface and in young leaves (Pecetti *et al,* 2007) and their concentration tends to increase with increasing stress (drought).

There appears to be a high level of variation in the furanocoumarin content of the Tedera accessions (Figure 5). It is not clear from the data provided what time of year the analysis of furanocoumarins was undertaken.

Although none of the mature Merino wethers grazing tedera to date at Mt Barker has shown signs of PS, further studies and ongoing monitoring are planned.
Other secondary compounds (phenolics) could be responsible for low grazing preference in winter (Pecetti *et al* 2007).

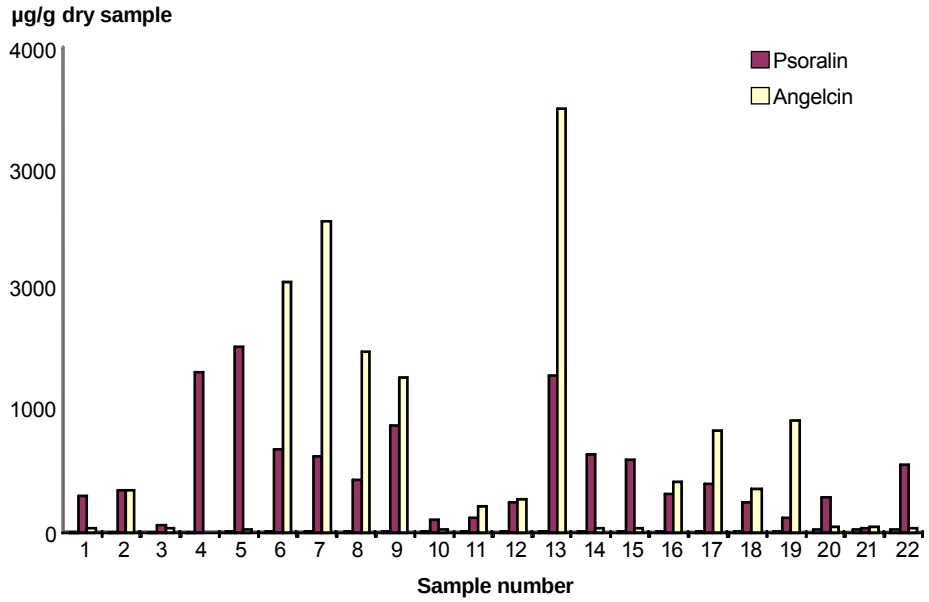

Figure 5. Psoralin and angelicin levels in 22 accessions of Tedera varieties (Oldham, unpublished).

5. Grazing management

It appears from inspections of the sites in WA that hard grazing tedera to ground level has produced the most favourable growth response. Plant material cut at the Medina Research Station (south of Perth) left hard, unpalatable stalks to 0.5m in height (Figure 6). These sharp stalks could be a hazard to vehicles driven over the paddock.

Figure 6. Tedera stalks remaining after cutting to 0.5m height.

Regrowth after grazing to ground level at Mt Barker appeared to be highly digestible with soft stems and plants with a large proportion of leaves.
Overseas studies indicate that rotational grazing four times per year is the optimum grazing management.

6. Potential stocking rates
The key to adoption of tedera in low rainfall farming system will be its carrying capacity, lamb and calf growth potential and ease of management.

For example, 500 lambs grazing for 100 days require 75t DM of high quality feed. For 2 t/ha food on offer less the 500kg residual not grazed will require 50ha of tedera.
The lower the DM production of the tedera the larger amount of land required to finish lambs.

Stocking rate potential will be limited in sandy soils unless significant amounts of interrow pasture are established which in turn may limit the productivity of the tedera.

7. Grazing options: Tedera vs. alternative pastures vs. pasture mixes
There has been little assessment of how tedera would perform if it was sown as a component of a pasture mix. Current row spacings are approximately 1 metre which would not allow for establishment of inter-row crops or pastures.

The growth pattern of winter active lucernes or perennial grasses may well complement tedera however this has not yet been determined.

Establishment of widely spaced rows to facilitate sowing of winter cereals would be worthy of investigation when there are sufficient seed resources available.

It is appropriate to compare tedera with lucerne as a deep rooted perennial with summer activity however it may be that the species are more complementary than antagonistic. Further work would need to be carried out comparing tedera with summer active lucerne varieties.

D. Likely fit in farming systems

1. Adaptability and persistence

The demonstrated tolerance of tedera to low rainfall situations and its adaptability to a wide range of soil types indicate that it could have a fit over a wide range of environments. The considered lower rainfall limit is 250mm annual rainfall. As well, it has persisted well during some very dry years in trials sown at several sites in WA in 2005 or 2006. It has also recovered well from defoliation by locusts (at Bealiba, Victoria) and to a less extent from a heavy infestation of rabbits (at Merridin) and being overgrown with weeds (at Hamilton).

There is a need to continue maintaining and monitoring some existing trials to establish the longer term persistence of tedera.

2. Likely extent of production in southern Australia

We consider that tedera is likely to be grown only over a much smaller percentage of the area considered suitable by the research team. Their estimate of more than 12m ha is based on the area considered suitable for lucerne (Robertson 2006).

While it appears to be more drought tolerant than lucerne in some situations there are several factors that will restrict its likely area:

i). The likely high cost of establishment making it unattractive for growers in more marginal farming areas.

ii). The general lack of interest by most growers with cropping/livestock enterprises to grow a perennial in rotation with their cropping. This is especially in the medium to lower rainfall cropping regions. As well, as the cost of establishment many growers now are not set up to gain an economic return from grazing due to lack of infrastructure and expertise. There can also be a negative impact on crop yields sown after a perennial pasture due to less plant available soil water.

iii). Tedera also needs to compete economically with other pasture alternatives, such as lucerne or annual sown pastures, including cereal or pulse pastures.

Our view of the likely extent of tedera uptake by growers is based on several examples, including lucerne, of optimistic claims of the extent of production and the much lower uptake that eventuated.

Tedera may have some potential on poorer lighter soils in these regions where the profitability of cropping is poor. It could also have a fit in mixed plant systems, such as with tagasaste. The review committee considers that these are likely to relatively minor.

It is recommend that future research on the adaptation, growth and persistence of tedera under grazing as a permanent pasture is in the 400-600 mm rainfall zone on the less arable lighter textured soils of the southern Australia, principally in WA.

3. Modelling plant production and the economic value in farming systems

i).. Biophysical models

GrazFeed's associated model, GrassGro, is a reliable and comprehensive plant growth model and it would be helpful if it could be employed to predict the area suited to and the production of tedera. However many widely adopted species and cultivars are yet to be incorporated into that important management tool; these may claim priority.

ii). Assessment of the MIDAS modelling of the value of tedera

Well constructed mathematical modelling is an excellent research method to assess the potential of a farming system component, especially where 'scarce knowledge' occurs on a subject, such as the place of tedera as a grazing pasture species. The strength of the improved understanding from the modelling depends very heavily on the assumptions used and the relationships being modelled. So, the use of MIDAS, with it reputable modellers, is a good tool to be used to assess the place of tedera in the Australian farming system.

The strengths of the models outcome are based on the assumptions, and it appears in the tedera MIDAS modellers have correctly 'erred' on the conservative side with their major assumptions.

a). Tedera had an 80% DM production compared with lucerne
b). The DM carryover for tedera between seasons is excellent
c). The palatability of tedera is equivalent to lucerne, and so has a positive impact on livestock production.

The big issue is that the research results currently know of tedera is that there is a low level of confidence, even in the conservative assumptions used in the tedera MIDAS model.

The major outcomes form the tedera MIDAS modelling are that

a). Tedera's major role in the dryland farming system is by providing feed in the autumn feed gap. Traditionally farmers have used supplementary feeding of grain and hay fill the feed gap.
b). Tedera appears to have a greater role in the medium to low cropping rainfall regions of Australia

The major unanswered questions coming from the tedera MIDAS modelling from a farming system point of view:

The biggest challenge to these results is that there has been little research work with tedera on a 'farm scale' basis to verify the major assumptions. That is, it is not clear farmers will experience research benefits when using Tedera on their farms. So, there is a major need to replicate the tedera research using 'farm scale' methods.

a). It is understood that the seed costs of at least $100/ha will be needed to establish tedera. If this is the case farmers will view this as very expensive when comparing to the alternative of spending $3,000 - $8,000/farm for supplementary feeding to fill the autumn feed gap.

b). Currently, little pasture establishment and maintenance occurs in the medium to low rainfall cropping zone as the economic returns from livestock enterprises has been poor, when compared to cropping. This has changed a little with the recent significant increases in sheep, wool and cattle prices. So, farmers may now become more interested in improving their pasture production in these medium to low rainfall areas.

iii). <u>Costs and benefits needed for a farm scale analysis</u>
The benefits that will need to be modelled are:
a). Is livestock production (meat and wool) improved compared to the alternative autumn feed gap strategies?
b). Have the livestock carrying capacities improved because of tedera?
c). Has the quality of livestock production improved because of tedera?
d). Are labour requirements needed to manage tedera lower than the alternatives?
e). What are the positive impacts of a tedera phase on the economic returns of subsequent crops?

The costs that will need to be modelled are:
a). The cost of tedera pasture establishment
b). What are some of the issues that come with using tedera, such as animal health, quality of production and lambing and calving percentage.
c). What are the negative impacts of a tedera phase on subsequent crops?

E. Identification of other forage programs and opportunities that may deliver a similar outcome

Given such an all-compassing spread of environments that the tedera research team has outlined for its use, a wide range of alternative species enter into consideration as competitors. Comparisons for both permanent pasture and phase cropping situations should be decided in consultation with relevant agronomists to ensure best options are included. This advice can now also be accessed readily for specific situations via Pastures' Australia regularly up-dated website: www.pasturepicker.com.au The following species are likely considerations:

i). For permanent pasture:

These include lucerne, perennial grasses (including kikuyu and *Panicum*), annual clovers and medics, chicory, plantain and perennial legumes such as tagasaste and *Lotus corniculatus.* In Mediterranean environments grasses include winter-active phalaris and tall fescue.

For areas with less than 400mm rainfall, there will be fewer perennial species suitable – lucerne, tagasaste, small leaf bluebush, old man saltbush, river saltbush, perennial veldtgrass and many annual legume options including clovers, medics, *Biserrula, Ornithopus* and *Vicia* species. While tedera should persist well in some of these low rainfall districts, its high cost of establishment will restrict adoption unless its feed value is exceptional.

ii). For phase cropping:

These include lucerne, perennial grasses, annual clovers, medics, vetches, peas, chicory, plantain and perennial legumes such as *Lotus corniculatus.*

F. Recommendations for modifications to the MLA proposal

1. Project details

While the project team produced a lot of informative material, but it appeared not to be well coordinated across different organisations. The review team has found further bits of relevant information that were not incorporated in the presentations. There is a need for a concise summary of the research plans of all the various research participants. This is needed in order to more clearly identify the most important knowledge gaps, a prerequisite for a full proposal.

In preparing a full proposal the leaders should determine

a). Clear (SMART) project objects

b). A research plan which includes the appropriate skills to manage these programs.

We did not identify major gaps in the research components. There were rather too many components which did not have any priority rankings.

We recommend that research subprograms be ranked into two priorities and funded in two phases. The second phase is to be funded only if the first phase shows a strong indication that tedera is likely to be commercially successful.

The components and rankings are as follows:

Component	Phase	Comments
Seed increase for grazing trials	1	Budget appears excessive*
Sheep & lamb production	1	One site or two?
Plant production in grazing trials	1	Especially at critical times of the year
Nutritive value	1	A critical component
Herbicide tolerance	2	The UWA study should be sufficient for guidance on herbicide use in grazing field trials in phase 1.
Plant production in NSW & Victoria	2	
Paddock grazing trials in NSW & Victoria	2	
Glasshouse expts. on subsoil constraints	2	
Herbicide data for registration	2	An expensive process so only do this if commercialisation is likely.
Companion species	2	
Seeding agronomy	2	Quite a lot is know already
Drought tolerance	2	Quite a lot is know already
Fertiliser responses	2	Appears not to be especially intolerant of specific nutrients
Economic modelling	2	Unlikely to influence commercialisation.
Biophysical modelling	2	

* Seed build-up costs will be $760/kg for the estimated 480kg of seed produced with the current budget. We estimate that sufficient seed for grazing trials could be produced in the first year.

For the proposed grazing trial with 3 reps and 1 ha plots, the following points needs to be clarified:
a). Whether the reps will be grazed on rotation or all 3 will be grazed continuously,
b). Whether tedera be grown pure or with companion species to stimulate winter production and

c). Whether the plots will be grazed all year or will tedera production be 'stock-piled' for use in summer-autumn following winter-spring deferment?
In the latter case, that is, a component of a sequential grazing system, there needs to be detail on what pasture the sheep will sequentially graze while tedera is deferred. Sufficient of the deferred pasture must be sown to ensure animal production can be quantified for each feed system/group of sheep over the 'feed year'.

2. Project leadership & management
We consider the project team is strong in plant breeding but not as strong in agronomy. It also needs additional guidance in the animal production studies. We recommend that an animal production specialist with broad practical knowledge be also involved on a project steering committee. The research team needs to demonstrate that they have adequate links with expertise in entomology and plant pathology and farm economics.
There are concerns about their ability to manage a large multi-skilled project across a large geographic area. There are at least five cases of poor or failed field trials due to factors that should have been avoided. These include poor weed control at Mt Barker and Hamilton and rabbit damage at Merredin. Also field trials in SA several years ago were poorly managed and did not produce worthwhile results.

G. Recommendations on priority for funding for this or related alternate initiatives.
Within the feedbase budget, funds for development of pasture species, particularly novel species, need to be balanced against the opportunity to encourage the excellent proven technologies that are yet to be embraced by many producers.

The cumulative investment by RDCs in the development of pasture species over the past two decades is substantial. Considerable R&D has been carried out by the private sector as well. Much of the investment in legumes has gone into novel/'other' genera. It may be helpful to summarise the RDCs' funds invested in this area, the products developed and their volume of seed sales/royalties recouped.

Opportunities to stimulate investment in existing pasture species: Most of the important meat, wool and dairy-producing regions are well served by modern cultivars of staple species. As highlighted by Pastures Australia's recent modelling, the productivity of much of the land in good environments lags well below potential. The range in local productivity seen in grazed land is much wider than is the case with annual field crops.

Investment in novel genera will limit investment in existing technology deserving adoption. A balance must be maintained. Some opportune examples are suggested:

1. Animal production profits

There is a marked trend to expand the area of cropping. This is a real threat to the livestock industries. Can greater improvement in carrying capacity and in the rate of turn-off of prime stock be stimulated by R&D on reliable establishment and management of improved pasture and on experiments that compare poor pasture, old cultivars and modern high performance pastures in terms of the animal production that they can sustain in the long term? Improved cultivars have increased animal production (Reed 1994) but regional work quantifying such benefits are needed to help grow the confidence of producers, advisors and financiers in pasture improvement technology and in the comparative, long-term, economic returns that are achievable.

2. Adoption of phalaris

Despite some cultivation of novel and native temperate perennial grasses, Oram and Lodge (2003) outlined why the major species now in use would remain the staple species in the future. Phalaris is a most important and productive perennial species, relatively cheap and easy to establish. CSIRO have developed excellent science re its complicated genetics and biochemistry. They successfully improved seed yield, seedling vigour and winter growth (Reed *et al*. 2001). The adoption of its modern cultivars is good but the demand for them is tightly constrained by on-going concern with phalaris toxicity. Despite a recent advance in understanding the very complex toxicity problems with Phalaris, CSIRO have stopped the breeding program and closed their toxicology laboratory. With projected climate change this most drought tolerant species should become more important than it already is. RDCs could encourage seed companies to pick-up the ball by co-investing with them with a view to eliminating these toxins from the feedbase of our meat and wool industries.

3. Updating important tools

The computer-based decision support tools (GrazFeed and GrassGro) are used widely in Australia's grazing industries. GrassGro has serious limitations because the critical environmental factors limiting growth and controlling physiological development have not yet been defined and/or employed to make the model relevant for most of the well-adopted forage species or for modern contrasting cultivars of the species that are already catered for.

a). The pasture species (by old cvv – several >70 years old) accommodated in the commercial version of GrassGro are: -

perennial ryegrass (*cv* Victorian),
phalaris (*cv* Australian),

cocksfoot (a summer-dormant variety),
annual ryegrass (*cv* Wimmera),
barley grass, subterranean clover (4 cultivars),
annual medic,
lucerne (a winter active and a semi-winter dormant type),
white clover and
capeweed.

b). Some work has started towards inclusion of
tall fescue
chicory
further cultivars of ryegrass
further cultivars of cocksfoot
the warm-season grass, kikuyu and the
native perennial grasses: redgrass, wallaby grass and *Microlaena.*

c). But the improved cvv of phalaris (eg cvv Atlas PG, Landmaster and Holdfast GT), modern cvv of perennial ryegrass (representing marked contrasts in maturity, in ploidy, in endophyte status and in endophyte type), plantain, late maturing sub clover cvv, Rhode's grass and Panics are not yet represented in GrassGro.

Discussion & conclusions

Tedera is a promising perennial shrub species that *may* provide a source of quality feed for livestock over summer and autumn in southern Australian farming systems. It appears to have potential in medium rainfall zones where soils are free draining but its suitability in high rainfall zones where waterlogging can occur and low rainfall or drought-prone areas requires further investigation.

The value of tedera in more marginal areas such as the Victorian and South Australian mallee will depend on its economic value and costs of establishment compared with alternative feed sources, such as lucerne or cereals. An assessment of its productivity and persistence in these areas should be a lower research priority. In higher rainfall areas it may also be of value as an alternative to annual summer crop production such as sorghum and rape.

The clear research focus to date has been on plant breeding and selection and the safety of tedera to livestock. There are insufficient data available to properly assess the nutritive value of tedera to all classes of livestock or to assess its potential to increase the early joining potential of ewes, accelerate an annual lambing system or to increase the ovulation rates of mature ewes. One small autumn data set indicates tedera may have the potential to support the growth of young stock in autumn however the analyses have been undertaken at three different laboratories. There is significant variation in nutritive value across the

samples analysed, and many of the results are not necessarily representative of the more promising accessions being selected within the breeding program.

Dry matter production data are highly variable and the data set limited. The international literature reports a wide variation in preference and palatability across sites and seasons which have yet to be investigated in Western Australia, where it appears anecdotally that there is initial resistance to grazing, but eventual acceptance. The links between voluntary intake and the presence of secondary compounds have not yet been investigated or established. There was insufficient data available to properly assess daily dry matter production. While comparison with lucernes are well justified, summer active lucernes would provide a more appropriate benchmark than those that are highly winter active, such as SARDI 10 as used in the Mt Barker trial.

The amino acid profile appears to be similar to lucerne and the fatty acid profile similar to grasses. Claims that the vitamin E profile of tedera is likely to prevent a deficiency should be treated with caution as the vitamin E requirements for grazing ruminants have been significantly increased above the levels found in tedera in recent years.

The major feed gaps across southern Australia occur in winter and autumn. There appear to be questions that remain unanswered about the palatability of tedera during winter and very few plant samples have been analysed for nutritive value during winter. Those that have been analysed appear to be low in ME at a time of year when ME intake is often the most limiting factor to animal production.

The greatest scope for tedera in farming systems appears to be to fill the autumn feed gap however it is not yet clear as yet at what cost this would be. Tedera is unlikely to be able to compete cost-effectively with crop stubbles or standing crops in arable areas. Standing crops in similar rainfall zones to Mt Barker would generate conservatively at least 7 tonnes of dry matter per hectare at a cost of approximately $20/t DM.

The true cost benefit analysis of tedera establishment will be the comparative returns in all environments of retaining and finishing livestock rather than selling lambs and calves early.

Tedera appears to have good adaptability across a wide range of soil types and rainfall zones. It also has impressive drought tolerance and will retain leaves much longer than lucerne where there is moisture stress. There is potential to inter-sow tedera with other perennial and annual species such as tagasaste and subclover to increase livestock production.

The role for tedera across a wide range of farming systems remains unclear. There is insufficient livestock production data available to assess the potential cost benefit of tedera in a low rainfall system across a range of soil types. Other

uncertainties include the cost of establishment and the impacts (positive and negative) on crops sown after tedera. The review panel concludes that it is unlikely that there will be a large uptake of tedera in medium to lower rainfall cropping/pasture enterprises.

NRM benefits such as plant cover on saline or erosion prone soils appear limited. It is not particularly tolerant of salinity and in lighter soils grazing would have to be well managed to prevent erosion along rows. To limit the effects of wind erosion tedera could be sown in similar patterns to saltbush plantations.

A major potential limitation for the commercialisation of tedera is the likely high seed cost as a result of low seed yields and pod shattering. Low seed yields may also limit the availability of seed for larger scale field trials.

Further testing for herbicide tolerance is needed to establish which herbicides can be used for control of specific weeds in tedera in both commercial crops and in field trials. Trials specifically for chemical residues should be deferred until there is a clearer picture of the commercialisation of this species.

Other aspects of tedera pasture and seed production, such as seeding, plant nutrition, insect pests and foliar diseases appear not to be limitations. The potential for seedling root rots requires investigation.

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Appendix I. **Summary of answers to review questions.**

1. What is the adaptability of tedera to a wide range of environments?
A fair bit is known already from field trials in a few areas since 2006 already but there are some gaps, eg Mallee regions.

2. Are seeding systems well known across a range of soil types?
There do not seem to be any particular limiting issues here.

3. Is a specific rhizobium for tedera required and available?
Yes.

4. Issues with integration into pasture cropping systems?
A lot of gaps here but we don't see it as a high priority. Typically producer groups tend to work these out with some help from researchers.

5. Options for managing tedera in cropping rotations?
See no. 4.

6. Likely weed, disease & pest issues?
There are no major pest and disease problems so far. It is important that herbicide tolerance is resolved for both research trials and seed increase.

7. Management issues for seed production and economics of seed harvesting?
This is a high priority to be solved before commercialisation is feasible.

8. What other benefits can be realised from tedera?
There are possible NRM benefits but no greater than for lucerne. Other possibly uses such as pharmeceuticals or as hardy garden plants are presumably outside the scope of MLA.

9. Dry matter & nutritive value compared with other pasture spp. in a range of environments.
They have made a start but we still many see gaps here.
- lack of monthly DM data.
- DM data for summer and autumn, ie in the fed gap.

- NV data within sites over time.

10. Production of tedera at different times of the year & will it address fed gaps.
There are also a lot of gaps here.:

11. Are there palatability or adaptive issues?
Yes, more work need to assess these & management to minimise them.

12. What are the best practice grazing managements?
Still to be worked out. No doubt depends on livestock enterprise, etc. Other studies indicate that it need to be rotationally grazed.

13. Are there other forage types which may be improved to address the opportunity indicated by tedera – but at less risk
There is a strong case to fund greater adoption of existing pasture species in preference to establishing tedera. Refer to paper by Kevin Reed for more details. The most likely fit for tedera is likely to be in the 400 to 600mm zone.

14. What may constrain commercialisation of tedera?
High seed cost. Possibly palatabilty. Not as economic as cropping in the cropping/grazing zone,……

Whole farm economic & NRM questions:

15. Likely impact on grazing profitability
Too early to tell. Need to know impact on other livestock enterprises, such as prime lambs.

16. Likely persistence?
Has survived up to 5 years but longer term persistence not known.

17. Impacts of tedera on subsequent crops?
See no. 4.

18. Likely impact on whole farm profitability across a range of environments and grazing enterprises?
Insufficient information to decide this yet.

19. Impact of growing & grazing tedera on NRM issues such as wind & water erosion and on soil water table?

Likely have some benefits compared with dry annual pasture over summer and autumn. The tolerance of tedera to salinity has not been well demonstrated yet.

Appendix II. **SWOT analysis and research gaps**

Strengths	Main evidence	Questions/comments
Drought & heat tolerance	Well established by Spanish and Australian physiology studies and observations elsewhere.	
Grazing tolerance	16 year study with cattle in Israel under both deferred and continuous grazing. Recovery from rabbits at Merredin WA and from close rotational grazing with sheep at Mt Barker WA	Information desirable re continuous grazing by sheep
Soil requirements	Suited to well drained, light textured acidic and alkaline soils.	Suitability to water-logged heavy textured soils? Not as productive on alkaline soils on Eyre Peninsula.
Nitrogen fixation	Nodulates readily in native environments and supply of its meso-rhizobium is not considered a problem.	No data on N fixation benefits in phase cropping rotations. Possible need for comparing rhizobia strains at other sites.
Herbage production	Out-yielded lucerne in WA & NSW in short-term trials with yields of up to 10 t DM/ha when irrigated.	Seasonal DM production from a broad range of soil types. Response to soil fertility.
Seasonality of growth	Grows year round and makes considerable growth in dry months in Mediterranean climates	Poor growth in winter in temperate climates? Use of winter-active perennial grasses and/or sub clover to complement low winter production?
Digestibility – in vitro	Up to 80% *in vitro* (Milton) for spring herbage but there are no other data to support these figures.	Predictions are based on calibration.
Nutritive value	Lab tests imply NV is maintained well over time (both in the plant and in the fallen leaves) allowing quality feed to be deferred for grazing in the dry season. High proprionic % in VFA	NV data is highly variable – appears good for maintenance but insufficient data for growth estimates at this stage. Data needed on voluntary intake. Good efficiency of

	relative to lucerne.	utilisation if nothing else on offer but high variability between plants. Response to soil fertility?
Anti-nutritive factors	Despite the presence of 4 furano coumarins the there has bee no occurrence of photosensitization yet.	Need to test for photosensitisation in wetter years. Further study is now being undertaken by DAFWA.
Meat taint	No taint in young wethers meat - after 44 days on tedera at Mt. Barker	
Weaknesses		
Cost of seed	With seed yields of 200-400 kg/ha and a germination of 80%, the amount required for broadacre commercial sowings (5-10 kg/ha) is likely to cost over $100/kg.	Sowing rates and row spacings have yet to be determined across a range of environments Seed production has been a major factor limiting broadacre adoption of *Lotus* (Ayres *et al*. 2008) *Trifolium ambiguum* and native grasses
Trafficability	Where ungrazed or mown, the thickness of the woody lower stems of the shrub's stubble may be perceived a hazard for conventional motor tyres.	Possible need to plant in blocks to provide traffic access.
Digestibility – in vivo	60% - (DAFWA pen study)	Equivalent to 8.5 to 9 ME. This is not going to drive growth, weight gain in weaners.
Weed control	Annual broadleaf and grass weeds out-competed tedera at Hamilton, VIC.	Information needed on selective herbicides?
Weediness	Passage of seed through sheep will spread plants into arable paddocks	

Pests and diseases	Maybe vulnerable to mealybug – a potential disease vector.	No problems found to date by research team.
Opportunities		
Natural resource management	Use for erosion control and for lowering recharge where salinity is a concern.	More assessments need on tolerance to salinty.
Asset protection	Possible use as a firebreak.	
Apiary	Long flowering types maybe suited for honey production.	
Horticulture	Use as a hardy ornamental ground cover.	
Pharmaceuticals	Possible use of plant secondary metabolites.	
Seed exports	Foreign rangelands or mixed farming markets, eg Africa, Middle East, Americas	
Threats		
Seed supplies	Better profits from high-yielding crops (eg. cereals, lucerne or annual legumes) may restrict the uptake of low-yielding tedera as a seed crop	
Feeding value	-	Lack of detailed information
Unpalatability	Mentioned in literature. Noted by researchers in WA, SA and VIC. A threat to adoption by some meat producers There appears to be variability across accessions and varieties. Also no nitrate information. Need to sort out whether its unpalatable or just unfamiliar (neophobia).	ISCF research (Italy) found tedera contains a wide range of volatile compounds in leaves and flowers. These include sulphurated compounds with a “very low odour threshold”.

Research and development required to address weaknesses & threats

1. Demonstrate levels of livestock productivity above maintenance levels with realvant grazing experiments

2. Investigate any anti nutritive factors and animal health issues further – intake and photosensitisation

3. Increase seed yields.
i). Higher seed yielding genotypes
ii). Seed rate x spacing experiments to maximise seed yield.
iii). Best environments for high seed yields: soil type, climate.
iv). Best management for high seed yields: irrigation?, nutrition, grazing timing &intensity, desiccation &/or swathing.
v). Best harvesting system: conventional or specific machine (currently available or purpose built).

4. Investigate further plant growth rates in different growing environments.
What is its production in other areas in southern Austrailia, esp alkaline mallee soils.
Suitability in salty areas.
Response to soil fertility.
Seasonal growth patterns
Complimentary pasture species to include to increase production

5. Investigate fit in different farming systems, including phase farming and shorter term breaks in continuous cropping
Data on N fixation.
Tolerance to herbicides.
Registration of herbicides.

Appendix III. **Personnel contacted**

DAFWA: D. Real, M. Ewing, C. Revell, C. Oldham, J. Moore
UWA: M Ryan,
NSW I&I: G Sandral
VIC DPI: S Clark, Z Nie, M Raeside
SARDI: R Latta
RIRDC: J. de Majnik
CSIRO: Michael Robertson
AusWest Seeds: J O'Brien
PGG-Wrightson Seeds: J Sewell
Stephen Pasture Seeds: A Streeter
Global Pasture Consultants: N Ballard
Specialty Seeds: L Meyer
PastureWise: S Kemp
Seed Distributors: I. Freebairn
AKC Consulting; Kevin Bodurak

Appendix IV. **Evaluation of project proposals aimed at developing novel pasture species**

By Kevin Reed, Reed Pasture Science.

Review of literature

Have the proposers demonstrated awareness of relevant reviews of the literature around their target species and around similar concepts? Across the winter-spring rainfall regions of Australia the problems of pasture may be simplified as 3-fold: (A) Its low quantity in the cold months limits carrying capacity, (B) its low quality in the dry months weakens its feeding value and (C) the high costs of its establishment and maintenance. Many reviews have been commissioned by eg Standing Committee of Agriculture and R&D Corporations on the limitations of pasture species and on (B) in particular.

AWC-commissioned research into diverse perennial legumes in late 1970s concluded with advice that ~75% of future work should focus on the broad genetic diversity within the complex of perennial *Medicago* and *Trifolium* species - and 25% be directed towards novel/other genera. Numerous genera have been evaluated. Quite significant investments saw MRC/MLA, RIRDC, DRC/DA and/or AWC/AWI commission work on *Lotus* spp., *Astragalus* spp., Kura clover (*Trifolium ambiguum*), *Onobrychis trifolii* (sainfoin), *Chamaecytisus palmensis* (tree lucerne/tagasaste), *Dorycnium* spp. and *Hedysarum coronarium* (sulla). Many cultivars were released following these legume projects and some of the genera have been the subject of several rounds of investment; some extending the work and some taking different approaches within the same genera. Do the RDCs refer to a table listing their investments and showing the outcomes in terms of completion (eg cultivars), adoption (eg royalties) and feedback (eg expanding seed sales vs time)?

To date the general demand of these other legume genera by livestock producers remains low [the usage of many tropical legumes developed in the 1970s has not been sustained]. However, the need for summer quality is certainly recognised by southern meat producers. Their use of seed imports of the highly-productive annual *Brassica* fodder spp., as well as of the perennial summer-active herbs, plantain and chicory soundly illustrates their awareness of the problem. Many of the same teams involved with legume improvement have witnessed the success of their new improved annuals including subterranean, Persian, balansa and other clovers and serradella spp., peas and vetches - some of which also improve the summer quality of feed be it through late finishing, deferred use in the case of species that hold their nutritive value well, or as conserved fodder.

Project components

The researchers need to demonstrate an appreciation of the likely genetic diversity and steps to obtain and evaluate it. This needs to be based on the most

likely environments which in turn need to be important or potentially important for meat production. Preliminary information must be developed on establishment. Annual DM production and persistence under grazing need to be addressed in comparison with the best pastures suited to the environment as agreed on by local agronomists. This work is needed across as wide a range of likely environments as possible and not state-centric. Nutritive value testing needs to be carried out and animal production relative to benchmark species should be measured soon. With some research providers the links between plant and animal science are not close and the grazing of plots and the measurements of animal production are deferred. Such involvement should be strongly insisted on with appropriate investigation of anti-nutritive factors and/or animal health and welfare issues. By the 2nd or 3rd phase of funding there should be sound information on seed yield and sustained animal production/ha at a competitive level over several years. After 3-5 years research, unless the team have obtained strong offers of investment of seed companies, the likely commercial success of the species, must be seriously questioned.

Seed production is a major problem. Despite optimistic proposals to improve it, there is a global problem with obtaining seed at competitive prices from *Lotus* species and *Trifolium ambiguum* and to date this has greatly restricted adoption despite practical evidence and many scientific papers testifying to the value of these species. Surveys reported by Harris *et al* (1993) and Ayres *et al* (2008) identified seed cost/seed production as a significant factor involved with the low adoption of *Lotus*.

Where selection/plant breeding is planned, the objectives and genetic strategies need to be clear and the expertise demonstrated. Supported links with biochemists, pathologists and entomologists need to be considered and provided where appropriate. A clear timeframe to commercial release and interest from seed companies should be requested.

In responding to the difficult RDC questions about likely economic impact, teams often describe the area of suitable land and place much emphasis on that and then indicate a (conservative?) % adoption. 25 years ago plant breeders estimated that the potential area in Australia (inclu the semi-arid zone) where the environment would sustain annual medics was 70M ha. Predicting adoption/usage relies on not just environmental factors however. Decision makers must also take into account the alternative species/strategies, establishment cost and seed supplies, extension/adequacy of management information, industry conditions (especially as affecting finance) and terms of trade.

Balancing the opportunities

Within the feedbase budget, funds for development of pasture species, particularly novel species, need to be balanced against encouraging the excellent proven technologies that are yet to be embraced by many producers.

History: Not all may be aware of all the corporations' history – at least within some discipline areas. RIRC cumulative investment in the development of pasture species over the past two decades is substantial. Considerable R&D has been carried out by the private sector as well. Much of the investment in legumes has gone into novel/'other' genera. It may be helpful to summarise the RIRC funds invested in this area, the products developed and their volume of seed sales/royalties recouped.

Opportunities to stimulate investment in existing pasture species: Most of the important meat, wool and dairy-producing regions are well served by modern cultivars of staple species. As highlighted by Pastures Australia's recent modelling, the productivity of much of the land in good environments lags well below potential. The range in local productivity seen in grazed land is much wider than is the case with annual field crops.

Investment in novel genera will limit investment in existing technology deserving adoption. A balance must be maintained. Some opportune examples are suggested: -

1. Animal production profits

There is a marked trend to expand the area of crop at the expense of pasture. Can greater improvement in carrying capacity and in the rate of turn-off of prime stock be stimulated by R&D on reliable establishment and management of improved pasture and on experiments that *compare* poor pasture, old cultivars and modern high performance pastures in terms of the animal production that they can sustain in the long term? Improved cultivars have increased animal production (Reed 1994) but regional work quantifying such benefits are needed to help grow the confidence of producers, advisors and financiers in pasture improvement technology and in the comparative, long-term, economic returns that are achievable.

2. Adoption of phalaris

Despite some cultivation of novel and native temperate perennial grasses, Oram and Lodge (2003) outlined why the major species now in use would remain the staple species in the future. Phalaris is a most important and productive perennial species, relatively cheap and easy to establish. CSIRO have developed excellent science re its complicated genetics and biochemistry. They successfully improved seed yield, seedling vigour and winter growth (Reed *et al*. 2001). The adoption of its modern cultivars is good but the demand for them is tightly constrained by on-going concern with phalaris toxicity. Despite a recent advance in understanding the very complex toxicity problems with Phalaris, CSIRO have stopped the breeding program and closed their toxicology lab. With

projected climate change this most drought tolerant species should become more important than it already is. RDCs could encourage seed companies to pick-up the ball by co-investing with them to eliminate the toxins from the feedbase of our meat industry.

3. Updating excellent modelling tools

The computer-based decision support tools (GrazFeed and GrassGro) are used widely in Australia's grazing industries. GrassGro has serious limitations because the critical environmental factors limiting growth and controlling physiological development have not yet been defined and/or employed to make the model relevant for most of the well-adopted forage species - or for modern contrasting cultivars of the species that are already catered for).

a). the pasture species (by old cv – several >70 years old) accommodated in the commercial version of GrassGro are: -

perennial ryegrass (*cv* Victorian),
phalaris (*cv* Australian),
cocksfoot (a summer-dormant variety),
annual ryegrass (*cv* Wimmera),
barley grass, subterranean clover (4 cultivars),
annual medic,
lucerne (a winter active and a semi-winter dormant type),
white clover and
capeweed.

b). Some work has started towards inclusion of

tall fescue
chicory
further cultivars of ryegrass
further cultivars of cocksfoot
the warm-season grass, kikuyu and the
native perennial grasses: redgrass, wallaby grass and *Microlaena.*

c). But the improved cvv of phalaris (eg cvv Atlas PG, Landmaster and Holdfast GT), modern cvv of perennial ryegrass (of contrasting maturity, ploidy, endophyte status and endophyte type), plantain, late maturing sub clover cvv, Rhode's grass and Panics are not yet presented in GrassGro.

Independent peer review of proposal

Involve range of specialists, organisations – including small seeds production, agronomy/ecology, animal science, farm management economics.
For breeding including geneticist, consider pathology, and entomology.

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Additional notes by San Jolly

From experience in sitting on the RIRDC Fodder Crops sub-committee for 7 years, the most effective model for project application review has been one that includes an advisory committee with a range of appropriate skills to include:

i). Governance - Chair
ii). Researcher
iii). Producer
iv).Consultant
v).Key industry players

This group signs an agreement to confidentiality which is enforced and any potential conflicts of interest are dealt with before the review of each proposal. Preliminary applications are reviewed, discussed and voted upon at a meeting. Full applications are then called for where appropriate and unsuccessful applicants are notified in writing as to the reasons. Full applications are then reviewed at a second meeting.
The project manager / Chair takes the process of contracting etc from there

The advantages of this process include*:*
i). It is a fair, equitable and efficient way to assess projects
ii). All components of the project are properly assessed to ensure it will meet its objectives
iii). Confidentiality is assured
iv). "Stealing" of others project ideas is greatly reduced
v). If many organisations have the same ideas, collaboration can be facilitated
vi). It ensures it will meet both practical and research needs

A more detailed discission paper by Kevin Reed on processes for evaluating research proposals on novel pasture species is attached (Appendix III).

Appendix IV. **Nutrient analyses of tedera**

Appendix V Nutrient Analysis of Tedera spreadsheet is available from MLA quoting Report PAS.0285. Summary data are presented on page 16.

3 August 2011

Appendix VI

Response to Final report of the external evaluation of tedera proposal produced by Allan Mayfield Consulting

Review summary

The reviewers report recommended that MLA fund a scaled back tedera project with priority one activity to produce animal production data in two grazing sites in WA. Seed increase in WA for these two trials was recommended, and as part of the grazing trials, plant production, nutritive value and palatability should be assessed. They recommend research on production agronomy in WA, NSW and Victoria and grazing trials in NSW and Victoria as a second order priority.

Context of tedera's importance to grazing industries

It is important to context the development of tedera against other species past and present for Mediterranean–like climates in southern Australia. In making this comparison we contend that no other herbaceous perennial legume that has been developed as a pasture species in Australia has such a remarkable ability to retain green leaf whilst retaining a level of drought tolerance as least as good as lucerne. This should allow fodder produced in late spring, summer and autumn to be utilised by livestock in mid summer and autumn when lucerne leaves have often been dropped in response to drought stress. This is a critical feed gap period in annual pasture systems and reducing the seasonality of green feed supply to livestock systems represents the "holy grail" of livestock production. We believe tedera is one of the few herbaceous plants known to be able to reliably target the summer/autumn feed gap.

In the context of grazing systems, our testing has identified that tedera potentially has a much larger landscape application than lucerne and that there are primarily three agro-ecological niches suitable for tedera: (i) tedera grows where lucerne grows with the added advantage of leaf preservation over summer/autumn which does not occur in lucerne when moisture and temperature stress is combined, (ii) tedera is more acid tolerant than lucerne (both to Al and Mn) and so it's adapted to a wider range of soil type than lucerne and (iii) genotypes of tedera have been identified that have tolerance to transient waterlogging where lucerne does not.

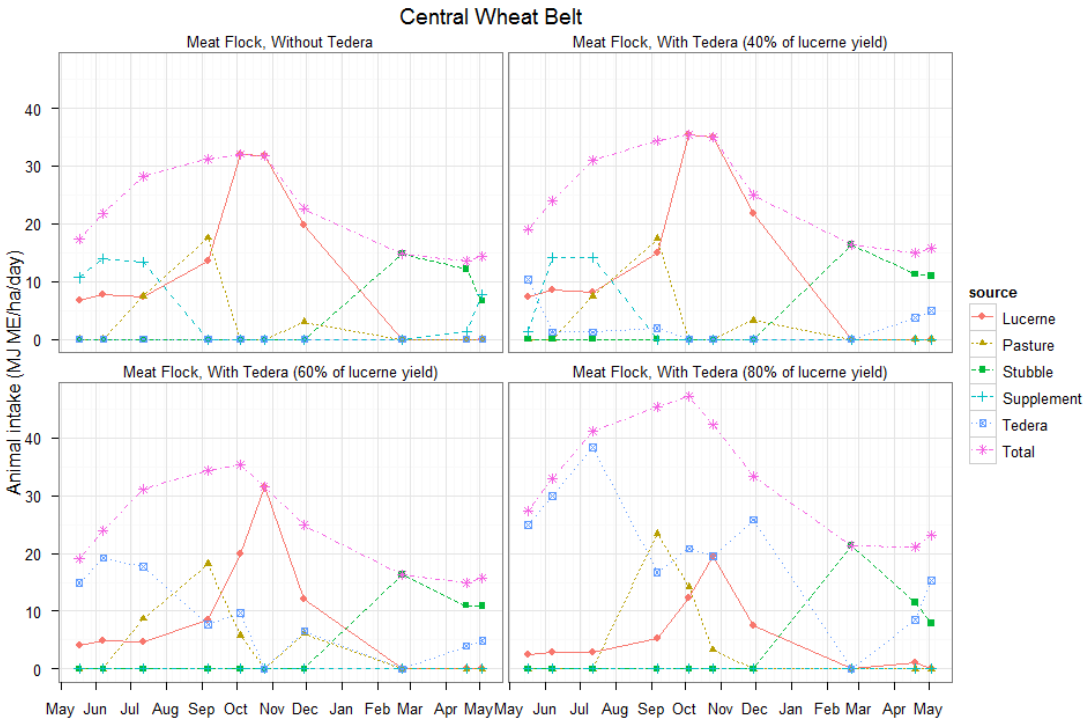
It is also important to note that tedera is not intended to replace lucerne, but it is intended to complement lucerne, annual pastures and other forages as part of the annual feedbase. An example of MIDAS model for the Central Wheat Belt of WA follows in which annual pasture, lucerne, stubbles and supplements are used with no addition of tedera (0%), or adding tedera as one of the components of the feedbase with yields of 40%, 60% or 80% of lucerne's annual yield (Data unpublished, Finlayson and Real 2011). Results of our field evaluations in WA and eastern Australia (unpublished data) provided similar annual yield for lucerne and tedera, however for modelling purposes, only a maximum yield of 80% of lucerne was used.

Flock	Yield of Tedera (relative to yield of lucerne)	Crop area (% of farm)	Annual pasture (% of farm)	Lucerne (% of farm)	Tedera (% of farm)	Stocking rate (DSE per ha)	Meat sales (kg per ha)	Wool sales (kg per ha)	Supp. feed (kg per DSE)	Farm profit ($ per ha)	Increase in farm profit due to Tedera ($ per ha)
Meat 0	%	78.8	6.9	14.3	-	2.0	25.9	5.6	66	95	-
40	%	70.1	6.9	14.0	9.0	2.2	28.6	6.2	44	97	2.0

60%	65.5	8.1	7.9	18.6 2	.2 2	8.6	6.2	0	106	11.0
80%	56.9	10.4 4	.8 27	.9	2.9	38.6	8.3	0	120	25.2

1: Farm area is 2000 ha (all per ha values are per ha of the farm)

Time of the year in which different feed components are optimised by the Central Wheat Belt MIDAS model is presented in the following figure when there is no tedera (0%) or tedera is included in the model with yields of 40%, 60% or 80% of lucerne's annual yield.



In summary the contextual consideration for tedera is that it targets the summer/autumn feed gap reducing the need for supplementary feeding which is one of the main problems in livestock systems, and it has a much wider application in the landscape than lucerne. In our view the significance of this was not adequately recognised by the report.

Priority two research as nominated by the report

There are several problems we see with the second tier recommendations made in the report for the proposed agronomy research in NSW, Victoria and WA along with the grazing systems research proposed in NSW and Victoria. The first is that tedera will not be able to be extended to the farming community without relevant information on how best to establish and manage tedera on-farm. This approach delays the benefits conveyed by tedera and the opportunity cost associated with this delay is far greater than the cost of the research proposed. Secondly we are concerned that this decision will result in no tedera research activity in eastern Australia, a potentially important market. To ignore these agro-ecological environments in the early development of tedera management would significantly reduce and delay the return on investment to industry.

Other issues raised by the reviewers

The reviewers expressed some concern regarding the organisation and leadership skills in the project, and that more strength was required in agronomy, seed production, animal nutrition and animal husbandry. The initial Future Farm Industries CRC research on tedera which started in 2005/06 has been broadened by the collaboration and good will of many researchers who have often added tedera to other research activities. On the surface, this may appear as an unstructured large project, but in fact it requires excellent leadership skills to be able to bring all these researchers together and generate as much information as has been presented in just four or five years. The project team does not support the view that more strength is required in agronomy, seed production, animal nutrition and animal husbandry, when the project team has input from 24 researchers from four State Departments and UWA, together with Landmark agronomist(s) and the Seednet seed company. We do agree that many other people can contribute to the development of tedera and all suggestions and recommendations in the report are welcome and will be fully considered and incorporated into a full proposal.

Even though the project team provided a comprehensive review of the project in May, some additional points of clarification and correction are provided below.

B . Plant production

1. Plant breeding and selection (Page 9)
    - Reviewers statement: enable two generations of tedera to be grown per year using tissue culture systems.
    - Comment: Should be “embryo and/or immature seed rescue and in vitro culture”.
2. Seeding and seedling establishment (Pages 9-10)
    - Reviewers recommendation: further research on establishment still required including seeding rates, row width for maximum seed production, impact of root rot and control of root rot.
    - Comment: Agree. This was part of the preliminary proposal submitted to MLA and remains a priority for the rapid development of tedera, because good establishment of tedera stands is essential.
3. Weed control (Pages 10-11)
    - Reviewers recommendation: much more testing is necessary to establish full range of herbicides, growth stages of application, response in different soil types and conditions, registration of herbicides on tedera.
    - Comment: Agree. This was part of the preliminary proposal submitted to MLA.

4. Plant nutrition (Page 11)
    - Reviewers statement: “but appears not to have a high level of tolerance to salinity or subsoil aluminium”.
    - Comment: Preliminary results indicate that it has tolerance to salinity, subsoil aluminium and manganese but requires further testing.

    - Reviewers statement: “it appears to be no more tolerant of waterlogging than lucerne in the few comparisons done so far”
    - Comment: Peer reviewed results indicate that it has more waterlogging tolerance than lucerne (Teakle N L and Real D. 2010. Preliminary assessment reveals tolerance to salinity and waterlogging (and these stresses combined) in Tedera (*Bituminaria bituminosa* var. *albomarginata*). In *Options Méditerranéennes*, pp. 151-154.)

6. Seed production (Pages 12-14)

- Reviewers statement: Because of low seed yield there is only limited seed for larger field trials, such as the proposed grazing trials.
- Comment: Low seed yield is not the limitation, rather the work has not been undertaken for the scale required (hence the proposal to MLA to bulk up seed for the grazing trials). We have only needed to produce a small quantity of seed of all accessions to have sufficient seeds available to evaluate genotype performance in small scale trials and the breeding program. Further seed increase will be required for selected cultivars coming from the breeding program.

- Reviewers statement: RIRDC project has been extended by a year to April 2013 because of a plant establishment failure in the first year
- Comment: The RIRDC project has been extended by one year because the technical officer that worked in this area took a voluntary redundancy package and no replacement was found with the required skills.

- Reviewers statement: There is a risk that the value of tedera will be oversold by Landmark and Seednet agronomists.
- Comment: We are not sure what the basis is for this statement. This can be applied to any seed company selling any variety. Landmark and Seednet are successful companies which pride themselves on providing credible information on the products they sell and they will not undermine their own credibility.

7. Production limitations due to insects (Page 14)

- Reviewers statement: include research trials for chemical registration to control pests in pasture legumes.
- Comment: Agree. This needs to be done as a second tier activity.

8. Production limitations due to diseases (Pages 14-15)

- Reviewers statement: root diseases should be investigated further including the use of seed fungicides.
- Comment: Agree. This needs to be done as a second tier activity.

10. Regional adaptation

- Reviewers statement: “there are still many areas in southern Australia where it has not been tested at all or very little”.
- Comment: Agree. This was part of the preliminary proposal submitted to MLA, but reviewers recommend support for only two grazing trials in WA and have not recommended any work in eastern Australia.

C. Plant nutritive value and animal production

1. Nutritive value for livestock (Pages 16-20)

v. Digestibility

- Reviewers statement: “the estimates of digestibility of 80% by John Milton require verification as they are based on calibrations using non-tedera material”.
- Comment: The digestibility values for all samples were determined by “Wet Chemistry” by the I&I NSW Govt. Laboratory at Wagga Wagga by the *In Vitro* Pepsin-Cellulase procedure and with appropriate standards of known *In Vivo* digestibility. The *In Vitro* digestibility procedure was carried-out in accordance with the methods outlined in the Fodder Analysis Manual of the Australian Fodder Industry Association Inc (AFIA). It is noteworthy, as pointed out during the presentation and shown in the data, both the ADF and NDF values are quite

low for all samples, which is consistent with a forage of high digestibility. Furthermore the elevation in propionate production relative to that for the Lucerne chaff in the actual *In Vivo* digestibility study is also consistent with forage of high digestibility – probably due to some readily fermentable components.

xiii. Vitamin E

- Reviewers statement: "content 37.8 to 85.7 mg/kg not sufficiently high to prevent a deficiency as they are significantly below daily requirements for all classes of sheep".
- Comment: According to animal health research scientist Gerard Smith from DAFWA the level of vitamin E present in tedera is sufficient to maintain health in young sheep. The recommended dietary level in sheep should be set to support a plasma level of > 1 mg/L. Results reported by Njeru et al. 1994 showed that lambs on rations containing 15 IU or 30 IU vitamin E per day had plasma vitamin E levels > 1 mg/L. This level is supported by estimated dietary requirements stated elsewhere. For example Puls (1994) states 10 – 30 IU/kg and Hidiroglou et al. (1992a) states 10 – 40 IU/kg. The range of Vitamin E content in Tedera has been reported as 37.8 to 85.7mg/kg DM (AS-11-2319, AHL 2011) that equates to 56 to 127 IU/kg.

2. Plant growth rates and animal responses from grazing (Pages 20-22)

- Reviewers statement: "grazing studies have been limited to date by the low level of seed production and ongoing selection of accessions that produced the highest amount of leaf material per plant.
- Comment: Grazing studies have been limited due to lack of seed increase for this purpose and lack of funding to do large scale grazing trials. It is not due to the low level of seed production and selection of accessions with good DM production.

- Reviewers statement: "it remains to be seen as to how much of this weight gain was attributable to the total feed on offer or the 15% tedera component.
- Comment: it is important to note that the 2400kg or 3000kg on offer of pasture was 50% digestible which would have been insufficient to maintain the liveweight of the wethers. On the other hand the tedera which comprised 15% of the sward was green and 75% digestible.

- Reviewers statement: "it was stated that there was a shortage of plant material that affected the trial. This is not supported by the available data in Figure 4.
- Comment: The shortage was of total tedera available for harvest for the experiment, so in order to have the experiment running for 40 days, we could not give 50% more tedera per day.

5. Grazing management. (Pages 24-25)

- Reviewers statement: "these sharp stalks could be a hazard to vehicles driven over the paddock".
- Comment: Agree, though we expect this will only occur under irrigation and with plants not grazed for long periods of time like at Medina RSU. Under grazing, plants will remain herbaceous as noted in Mount Barker grazing areas.

7. Grazing options: Tedera vs. alternative pastures (Pages 25-26)

- Reviewers statement: little assessment of how tedera would perform if it was sown as a component of a pasture mix.

- Comment: Agree. This is an area of research that needs to be done but we are getting good preliminary information from the Mt Barker 'duty of care' site. This was also proposed in the MLA project.

D. Likely fit in farming systems.

1. Adaptability and persistence (Page 26)
   - Reviewers statement: there is a need to continue maintaining and monitoring some existing trials to establish the longer term persistence of tedera.
   - Comment: Agree. This was part of the preliminary proposal submitted to MLA.

2. Likely extent of production in southern Australia (Pages 26-27)
   - Reviewers statement: Estimate of 12m ha as an optimistic claim of the extent of production (impact).
   - Comment: The results presented to the reviewers not only considered the potential area of adaptation, but also the potential area of adoption and that was 583,448 ha for all of southern Australia. This estimate of potential adoption was based on the following Table, using a probability of outputs produced (pO) of 95%, a probability of usage (pU) of 15% and a probability of land allocated to tedera relative to optimal area allocated by the MIDAS model (pMA) of 50%. It is also worth noting that research to dates indicates tedera has a larger adaptation range than lucerne.

	WA - Central wheatbelt	WA - South West	WA - South Coast	SA, Vic, NSW - Wimmera / Mallee	SA - Mid-north and Yorke Peninsula	NSW and Vic - SW Slopes and Riverine Plains	NSW - Central west	Total
MIDAS estimate of economically optimal proportion of farm planted to tedera	25%	31%	28%	25 %	25%	25%	25 %	26%
(pO) Probability that output(s) are produced	95%	95%	95%	95 %	95%	95%	95 %	95%
(pU) Probability of usage occurring	15%	15%	15%	15 %	15%	15%	15 %	15%
(pMA) Proportion of land allocated by farmers relative to optimal area indicated by MIDAS	50%	50%	50%	50 %	50%	50%	50 %	50%
Potential Niche (million ha)	2.5	2.6	2.	1 7 .8	2.2	7.	6 7 .0	31.8
Area of tedera (ha)	44,861	58,097	42,304	138 ,938	3 9,188	1 35,375	124,688	583,448

   - Reviewers statement: i) the likely high cost of establishment…
   - Comment: It is premature to say that the establishment cost is going to be high. The potential yield of more than 400kg/ha of seed for forage species is very acceptable. Further information on potential cost of seed, plant density, fertilizer requirement, herbicide requirement, etc. will be required before it is possible to derive an estimate of the cost of establishment.

3. Modelling plant production. (Pages 27-28)

ii) Assessment of the MIDAS modelling

- Reviewers statement: The biggest challenge to these results is that there has been little research work with tedera on a 'farm scale' basis to verify the major assumptions.
- Comment: Agree. That is why we submitted this project proposal to MLA.

- Reviewers statement: $3,000 to 8,000/farm in supplementary feeding.
- Comment: Not specified what costs are included in these figures (e.g. is labour included?) or where they might apply. These costs seem quite low and in addition, supplementary feed costs are considered by MIDAS when comparing the different models with and without tedera.

Discussion and Conclusions (Pages 33-35)

- Reviewers statement: The clear research focus has been on plant breeding and safety of tedera to livestock. Insufficient data on animal production.
- Comment: Agree. That is why we submitted this project proposal to MLA.

- Reviewers statement: "…nutritive value during winter. Those that have been analysed appear to be low in ME at a time of year when ME intake is often most limiting factor to animal production.
- Comment: The low values were from stem only samples. Winter is the time of year when tedera is the most leafy, so ME is as high or higher than the rest of the year. Tedera will also fill the winter feed gap until the annual pastures are productive enough to be grazed.

- Reviewers statement: likely high seed cost as a result of low seed yield and pod shattering.
- Comment: Tedera pods do not shatter and seeds yields are not low.