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Regional Development

GOVERNMENT OF
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MEAT & LIVESTOCK AUSTRALIA

Tedera: A guide to growing and utilising this perennial pasture legume

Contents

Author
Dr Daniel Real

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Cover image
Courtesy Dr Daniel Real

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Contact
Meat & Livestock Australia
Level 1, 40 Mount Street
North Sydney NSW 2060
www.mla.com.au
ABN: 39 081 678 364

Foreword

The commercial release of a new pasture species is a rare and, potentially, important event. In the case of tedera (*Bituminaria bituminosa* var. *albomarginata*) we have a novel perennial pasture legume with characteristics which set it apart from anything currently available to growers in Australia or internationally.

Specifically, it is a drought-tolerant, highly productive perennial pasture with the capacity to provide nutritious forage, especially when other feed sources are scarce. Its reaction to drought is in contrast with the few successful perennial legumes available for Mediterranean climatic zones, such as lucerne, as it retains green leaves when water stressed, allowing flexibility in the timing of grazing utilisation.

The research effort to deliver tedera has been systematic, innovative and protracted. It emerged from an initiative coordinated by the Cooperative Research Centre for Salinity in the late 1990s to identify new perennial pastures for southern Australia which combined high and efficient water use with productivity and potential for profit enhancement.

Large numbers of perennial pasture species were assembled for evaluation based on their known adaptation at locations of naturalised origin. They were then screened for several years in representative southern Australia environments. Tedera was one of the few candidates to display potential for further evaluation based on its growth, persistence and extent of adaptation.

By 2008 tedera had been identified as the only perennial legume in the program justifying continuing research.

A breeding program was initiated using genetic material collected from the Canary Islands to supplement material supplied by Spanish collaborators. A creative, focused and accelerated breeding program led by Dr Daniel Real produced the first 'domesticated' cultivar, Lanza® (T15-1218 ⦷), for commercial planting in 2019. An important and innovative aspect of the breeding effort was the early engagement of animal science collaborators to ensure the species was palatable with a high nutritive value. Animal scientists also tested for evidence of plant chemicals with potential for adverse impact on grazing animals. Another innovative aspect of the program was the use of the three years of seed increase prior to release to develop and test a robust seed harvest technique utilising standard cereal harvest equipment.

The breeding team led by Dr Real developed a package of agronomic knowledge fundamental in guiding the in-field efforts of early adopters of new plant technologies. The breeding team extended their commitment to delivering impactful research by drawing in key collaborators and coordinating a push to assemble key relevant agronomic information and then collate and interpret the results. Fortunately, Meat & Livestock Australia was an astute investor in supporting both the breeding and subsequent agronomic package development. This has allowed the WA Department of Primary Industries and Regional Development (DPIRD) to retain critical intellectual capacity and then draw in additional collaborators and funders to deliver a focused and impactful research effort across two decades.

This publication has assembled and organised much of the knowledge gained from the major agronomic research and development effort undertaken alongside a significant plant breeding effort. It provides strong guidelines to support early adopters of a novel plant species and system which has the potential to transform aspects of Australian livestock production.

Dr Mike Ewing

May 2023

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Researchers and collaborators

WA Department of Primary Industries and Regional Development

Plant scientists: Clinton Revell, Harmohinder Dhammu, Richard Snowball, John Moore, Angelo Loi, Geoff Moore, Marieclaire Castello, Richard Bennett

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Simon Crane, David Clegg, Caleb Hill, Peter Bostock

Bioeconomic modellers: John Finlayson, John Young

Agronomist: Phil Barrett-Lennard

Producers: David Brown, Richard Brown, Lachlan Brown, Zac Roberts, Michael Humphrey, Blair Humphrey, Kristin Lefroy

International collaborators

Spain

Murcia Institute of Research and Development (IMIDA):
Enrique Correal, Mercedes Dabauza, María Pazos Navarro, David Walker

Agricultural Research Institute of Canarias (ICIA):
Pilar Méndez, Arnoldo Santos

University of Murcia: José del Río, Ana Ortuño

University of Alicante: Segundo Ríos, Vanessa Martínez-Francés

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Introduction

This guide was developed to support producers and their advisors to select, grow and graze tedera for livestock production systems. Lanza® is a variety of tedera bred as part of the Australian research program and Lanza® seed is now available to growers. Research focused primarily on Western Australian farming systems and work is underway to test tedera across southern Australia. Another variety, Palma, is also being tested and may offer additional traits such as improved frost tolerance.

By making your way through this manual you will be able to determine if tedera is the right pasture for the situation. If it is, you will then be guided on how to sow it and utilise the resulting growth for optimum production.

This guide will help you decide if it is suitable for your system by considering:

- What is tedera?
- Are my soils suitable?
- Do I have the right climatic environment for tedera?
- Which paddock will I select?
- Can I sow tedera in the ideal window?
- What seeding system will I use?
- Can I supply best practice establishment support, such as weed control?
- Can I maximise its productivity through my grazing management?
- Do I have the right livestock system to make the most of the resulting productivity gain?

Section 1. What is tedera?

Tedera is a perennial legume for livestock production which offers:

- high drought tolerance and the ability to maintain green leaves through summer and autumn
- a deep root system
- the opportunity to extend the green pasture growing season into summer, reducing the need for supplementary feeding or feeding on lower quality feed, such as crop stubbles
- the opportunity to rest other pastures in preparation for the autumn break
- an increase in profit (modelling indicated incorporating tedera with annual pastures had a much larger impact on profitability than incorporating lucerne with annuals)
- hard seededness allowing slow breakdown over summer and autumn and reducing the risk of germination on false breaks
- tolerance to low levels of soil phosphorus, potassium and sulphur
- soil nitrogen fixation
- a self-seeding system which results in new plants and growth (which is not offered by lucerne)
- a safe, high quality food source for sheep and, potentially, cattle.

Tedera is suited to:

- most temperature zones, except those with extensive frost
- dry climates and rainfall zones down to 350mm average annual rainfall
- acid soil conditions (a soil pH ($CaCl_2$) of ≥4.8 is ideal, as it has some tolerance to aluminium (moderate tolerance compared with common perennial forages) and magnesium (the most tolerant of 11 common perennial forages when tested)
- areas prone to transient waterlogging (but this may affect its drought-tolerance levels due to poorly developed roots while waterlogged).

Where does tedera come from?

Bituminaria bituminosa C.H. Stirton is a perennial legume widely distributed in all countries surrounding the Mediterranean Sea. It is a diverse species with many botanical varieties adapted to regions with 150–1,000mm of annual rainfall from sea level to high altitude and from regions with no frosts to very cold mountain climates (Figure 1). *Bituminaria bituminosa* has many different common names depending on the traditional use and language spoken in the country of origin.

Tedera is the local name for *Bituminaria bituminosa* var. *albomarginata* in Spain's Canary Islands, where it grows naturally and is a component of native pastures grazed by livestock or used in hay for dairy goats in 'cut-and-carry' systems.

Tedera is a herbaceous (leafy and non-woody) perennial self-pollinating legume which has shown potential as a drought-tolerant forage for Mediterranean environments across southern Australia. Tedera grows year-round and growth is only limited by extreme drought conditions or low temperatures during winter. Tedera is a long-day (flowering induced by 12 hours of sunlight) plant, which flowers in spring and sets seed in late spring and early summer.

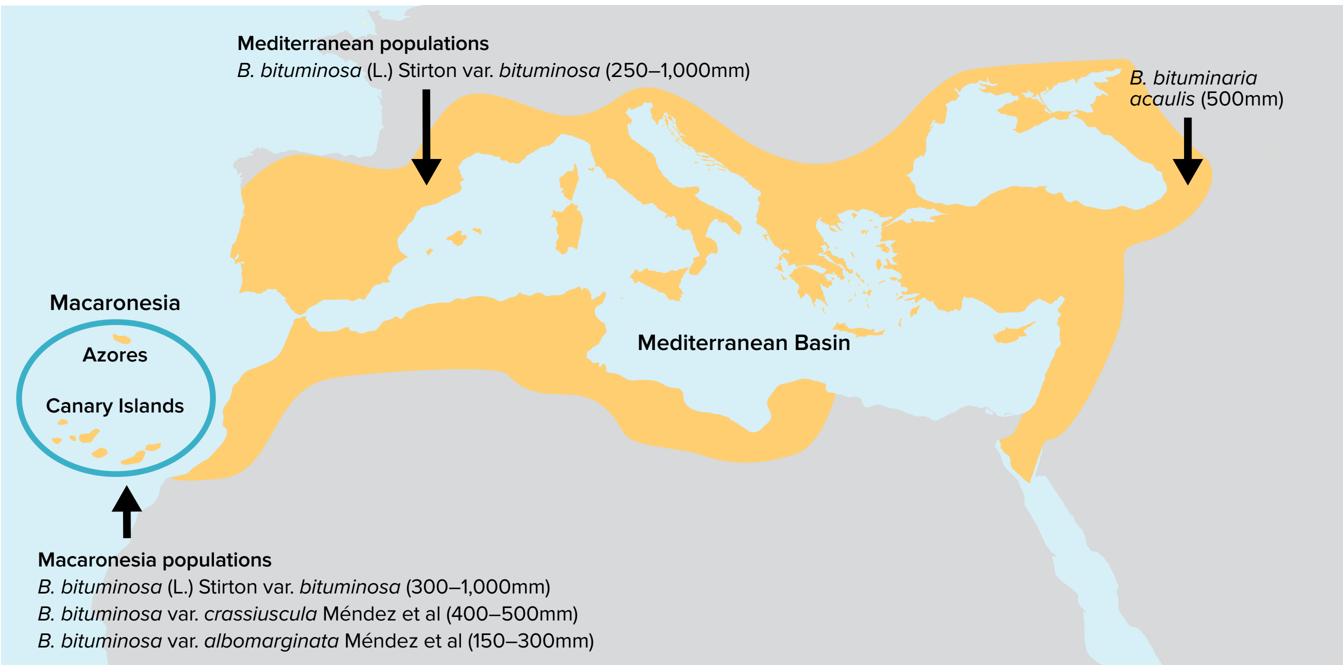


Figure 1. Distribution of *Bituminaria bituminosa* varieties in the Mediterranean Basin (in yellow) with their adapted rainfall range.

DID YOU KNOW

Tedera is closely related to the soybean, sharing 88% of its genes with the species.

Figure 2. The leaves and inflorescences (top left and right), immature and mature inflorescences with fruits (top middle), individual seed (bottom left), established plant (bottom middle) and processed seed ready for sowing (bottom right). Photos courtesy Dr Daniel Real and Peter Maloney.

How does the drought tolerance work?

A major advantage of tedera over known alternative perennial pasture legumes is an improved drought tolerance at both adult and seedling stage.

Aside from improving establishment and survival in low-rainfall areas, this drought tolerance results in improved ability to grow and hold green leaves under dry conditions which would cause lucerne leaves to desiccate and drop. These green leaves provide a valuable source of high value nutrition for livestock at a time when most other fodder is dry or non-productive.

The superior ability of tedera to maintain green leaves has been reported in glasshouse and field experiments. In a pot trial, lucerne leaves were completely desiccated within 21 dry days and growth ceased completely within 31 days. While even under extreme drought stress (47 days without water), tedera maintained green pliable leaves and growth continued, albeit at a low rate. This also enabled tedera to return to productive growth faster when given water, likely due to tedera maintaining an active growth state during drought.

In the field, it was found lucerne plants shed a large portion of their leaves in response to drought (63 days without rain), decreasing their leaf mass ratio (ratio of leaves to whole shoot biomass), while tedera maintained green leaves and had a leaf mass ratio four to six times higher than lucerne.

Researchers found tedera's drought tolerance is conferred through several interconnected biochemical and morphological attributes which maximise water extraction from drying soils, minimise water loss from shoots and improve water use efficiency.

These attributes include:

Maintaining leaf water content and function

Photosynthesis in growing green leaves requires water supplied by the roots and CO_2 from the atmosphere. Leaves are constantly exposed to water loss while exchanging gasses with the atmosphere through leaf stomata, and so maintaining the supply of water to leaves is critical for plants to retain functional green leaves under drought conditions.

Leaf water content can be maintained under drought conditions via a plant's:

a) ability to function at low leaf water potential (LWP) to draw water from soils with low moisture content

b) strong stomatal control to reduce water loss to the atmosphere, and/or

c) accumulation of solutes in the cells to increase osmotic potential and contribute to LWP.

Water use efficiency (WUE)

In trials, tedera has demonstrated higher WUE than lucerne in drought conditions. In young plants tedera's WUE was roughly three times higher than lucerne's WUE.

Tedera also produced higher biomass compared to lucerne, when both species received the same amount of water.

In another comparison between watered and droughted mature plants, tedera maintained approximately double the WUE in well-watered plants.

Morphological traits to reduce water loss

Tedera responds to drought over time by modifying shoot and root morphology to increase access to soil moisture and reduce transpiration. These leaf and root modifications are:

- **Paraheliotropism**

  Although paraheliotropism is not unique to tedera (also expressed in lucerne), it is a process exploited by tedera to minimise the leaf area exposed to solar radiation by changing the orientation of leaves. In tedera, the three leaflets on each leaf begin to fold along the midrib, point upward and close toward each other (Figure 4). The pointed leaflets then roughly track the path of the sun during the day. Research found this leaf behaviour in tedera could reduce the interception of sunlight by more than 50%, reducing leaf temperatures, transpiration and water loss. The extent of this leaf movement increased with increasing drought stress and more negative LWP.

- **Pubescence**

  Another adaptation to drought seen in tedera is the presence of fine lightly coloured leaf hairs or pubescence on shoots and particularly on the lower surface of leaves (Figure 4). These hairs play several roles in drought tolerance. The primary effect of leaf pubescence is to act as an insulating blanket, holding a small microclimate of cool moist air near the leaf to reduce transpiration from stomata. The light colour of the leaf hairs can also increase reflectance of sunlight, reducing photosynthetic demand for water and CO_2, and reducing leaf temperature.

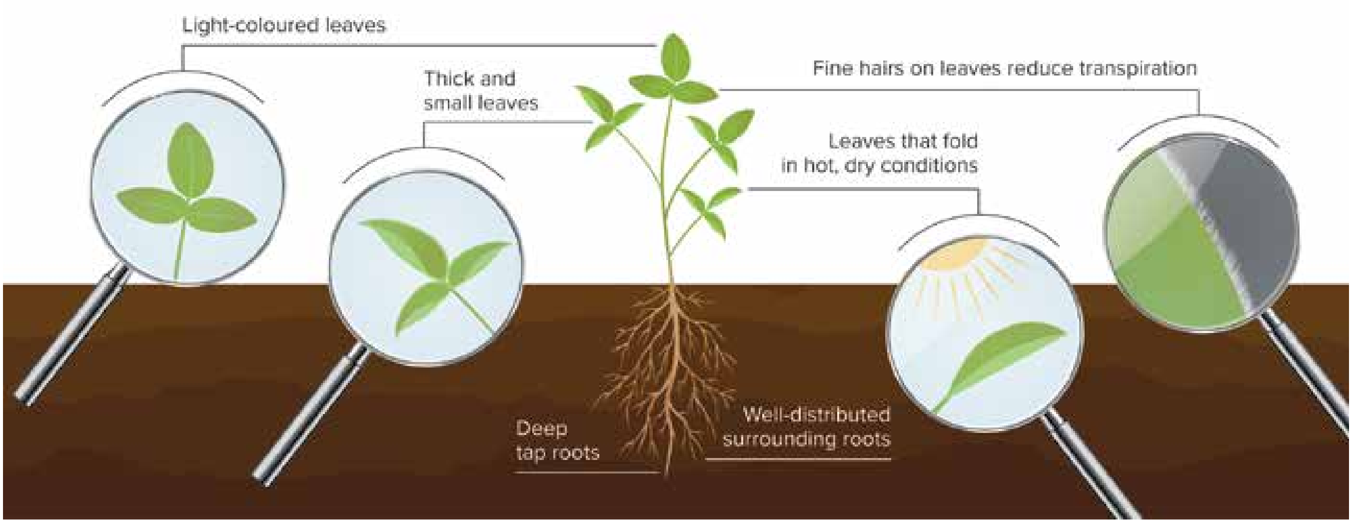


Figure 3. Why the tedera plant is good in a drought.

Figure 4. Paraheliotropism in tedera in February, 2010 (late summer, 63 days without water). Also note the strong pubescence on leaf margins and petioles and the folding of leaf lamina along the mid rib. Photo courtesy Dr Kevin Foster.

- **Leaf size and thickness**

  In response to prolonged drought, tedera has been observed to shed older and larger leaves, while new leaves produced are significantly smaller and thicker. Tedera has lower specific leaf area than lucerne under drought and watered conditions. Smaller and thicker leaves have a lower surface area per volume, allowing plants to regulate water loss and maintain temperature more effectively under high light intensity and low soil moisture.

- **Root distribution and plasticity**

  Early root development and penetration deep into the soil to access additional water is an adaptation to protect against potential drought. Tedera had the deepest taproot of the tested species in both well-watered and drought-stressed plants. Tedera taproots reached more than 40cm depth within 25 days in watered plants and within 52 days in drought condition plants. This early investment in roots penetrating into soil was likely possible due to the large size of its seed, thereby providing energy for early growth. Aside from a deep root system, tedera invests heavily in root biomass overall.

  Tedera responds to drought by changing the distribution of the biomass of the root system, while the distribution of lucerne roots does not change.

Let's get started

Growing conditions

To establish if tedera is suited to your production system you need to consider the proposed site's:

- **average annual rainfall**
- **temperature range**
- **soil type.**

How much rain does tedera need?

Lanza® tedera is a suitable perennial pasture in regions of WA with annual rainfall down to 350mm (Figure 5), with the limits of adaptation subject to soil type, rainfall distribution and sward management. Specific regions for tedera outside of WA are yet to be confirmed.

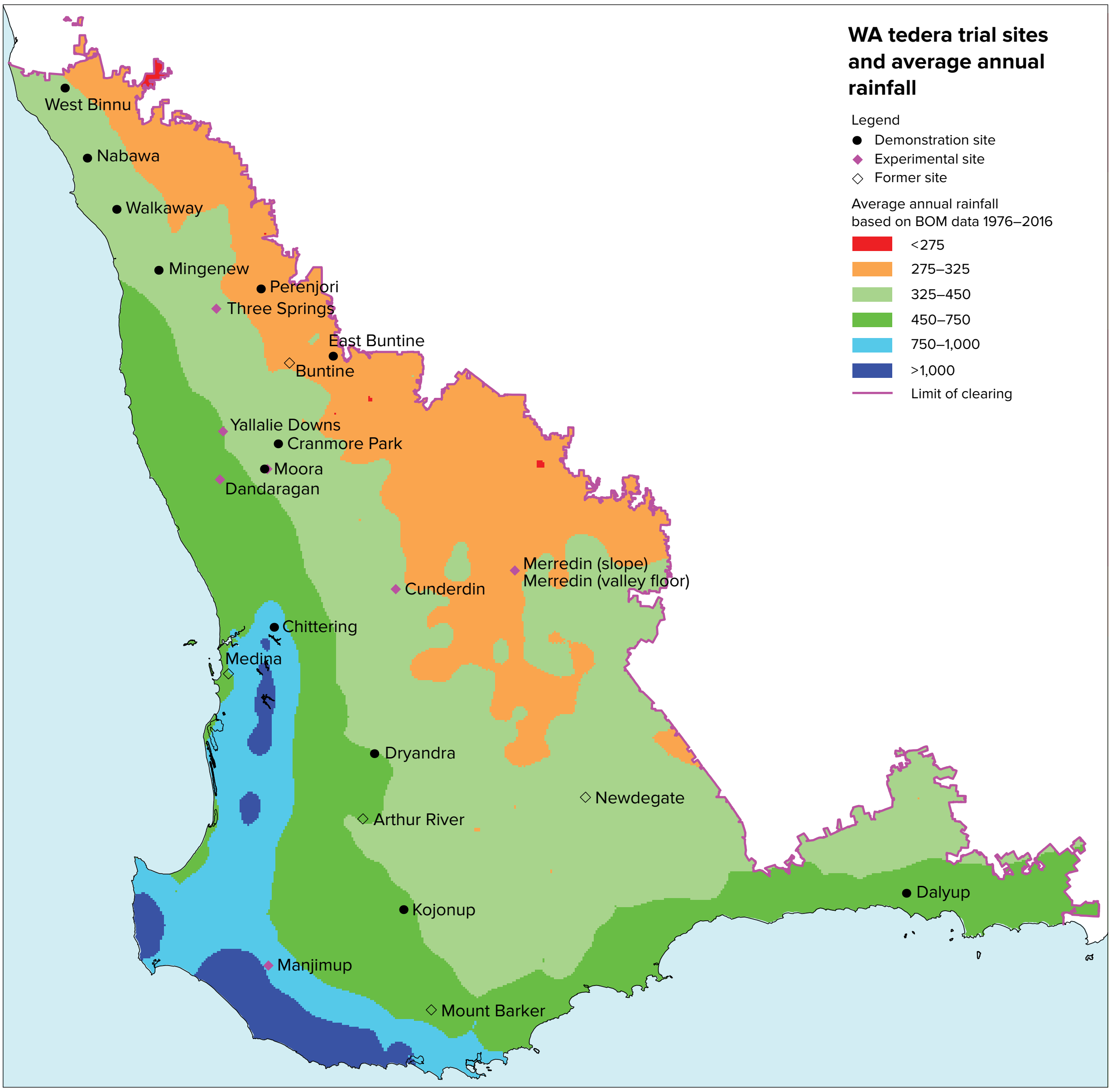


Figure 5. Tedera trial site locations and annual rainfall map (average 1976–2016) WA.

Figure 6. Tedera before the break of the season at Dandaragan in March 2018 (top left); March 2019 (top right); March 2020 (bottom left) and March 2021 (bottom right) from the same seed crop sown in July 2017. The photographs illustrate the accumulated growth between December and March, which were the hottest and driest months. Photos courtesy Dr Daniel Real.

The productivity of Lanza® tedera in response to management techniques was tested under dry conditions at Three Springs. This site was established in May 2017 and, while this site has a long-term annual rainfall average of 380mm, only 325mm fell in 2018. During 2018, Lanza® was able to produce roughly 2.5 tonnes of dry matter (DM)/ha.

At Buntine, irrespective of cutting frequency and density, survival of tedera (grown from transplanted seedlings in trials) was greater than 90% after 12 months and around 80% after two years. Plant deaths occurred primarily during the summers.

Dandaragan is in the medium to high rainfall zone (long-term annual average of 600mm) and has been the location of several field experiments and seed crops of Lanza® in which the variety has performed well. Dandaragan was extremely dry over this period compared to the long-term average (since 1900) with a rainfall percentile of only 4%. Since sowing the seed crop in 2017, the site had an average annual rainfall of 500mm.

An example of the ability of tedera to provide green leaf biomass after dry summers is presented in Figure 6 with a series of photographs taken in March 2018, 2019, 2020 and 2021 of the seed crop at Dandaragan sown in 2017. The seed crop was harvested in December 2018, 2019 and 2020 with a desiccant spray and subsequent cut by a commercial harvester.

In a study comparing productivity and persistence of perennial legumes at two sites in Victoria, research found tedera persisted and remained a vigorous grower much better at the low rainfall site. Survival and productivity of tedera remained good beyond three years at Bealiba (480mm long-term average), including during a drought year where only 275mm of rain fell, but the contribution of tedera to sward biomass at Hamilton (690mm long-term average) was poor beyond the first year, possibly due to the cooler winters, heavier soils and weed competition.

TOP TIP

Research revealed the optimal plant density for successful tedera biomass production is 16 plants/m^2.

Figure 7. Dandaragan seed crop on the 4 November 2021. Area sown in 2017 on the left and area sown in 2018 on the right.
Photo courtesy Dr Daniel Real.

What temperature suits tedera?

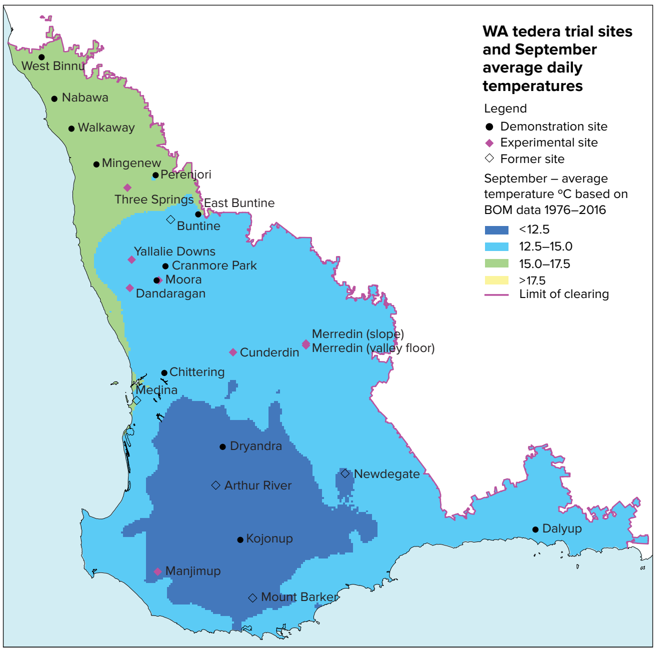


Figure 8. Average September temperatures in WA.

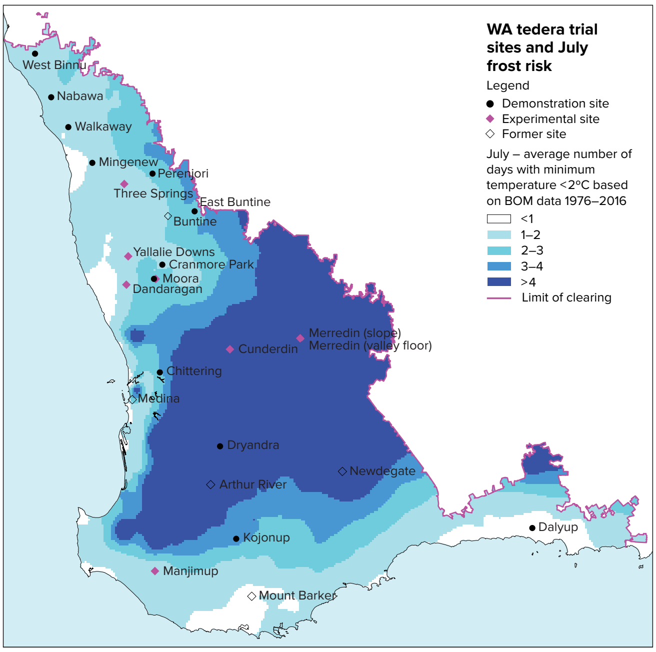


Figure 9. Number of frosts in July in WA.

Tedera is well suited to regions where temperatures are hot in summer and moderate in winter. WA maps of average September temperatures (early spring) and number of frosts in July are presented in Figures 8 and 9. Tedera grows best in early spring with average daily temperatures of 12.5–15°C.

The temperatures of WA's south west agricultural zone, even over summer, are no impediment to tedera growth, but winter growth is faster in warmer areas and with less frost. Severe frost in low topographic positions of the landscape can burn foliage and reduce the biomass production (Figure 10).

Lanza® tedera will tolerate mild frost during winter with minimal damage. However, late in the season, frosts that cause widespread damage to flowering crops like wheat will also cause damage to the flowers of tedera. Being an indeterminate flowering species, tedera will recover and a new set of flowers will be produced. If there are good rains in October/November tedera will be able to produce a good seed crop. However, if finishing rains are not significant, seed production will be constrained.

Figure 10. Tedera with frost damage (left) and tedera without frost damage (right). Photos courtesy Dr Daniel Real.

What soil type suits tedera?

Tedera can grow in many soil types with a range of textures, pH and fertility.

The long-term productivity and survival of tedera swards through multiple dry summers is dependent on the plant's ability to establish a deep root system to access subsoil moisture. For this reason, the most productive and persistent stands of tedera have been in deep sandy loams, deep loamy sands or deep duplex soils. Tedera can also be established and productive in valley floors with heavy soils or shallow duplex soils if sufficient soil moisture is available for plants to establish a deep root system over that first summer.

Waterlogging

Heavy soils which experience transient waterlogging for more than one month can also compromise the root system of tedera and survival over the following summer, even in mature stands. Tedera modifies its root system to enable survival during waterlogging; pruning deep roots and producing a thickened, shallow and spongy root system which increases gas exchange in roots. Such a root system exposes the stand to drought stress if waterlogging is followed by a long dry period.

While current varieties were not developed as waterlogging-tolerant pastures, tedera is generally superior in waterlogging and salinity tolerance to lucerne.

Salinity

Tedera was not developed for salt-affected soils, but does have good tolerance to salt compared to lucerne. Tedera's tolerance to salt and waterlogging as combined stresses is low.

However, tedera's salt tolerance will provide the greatest advantage during drought, allowing plants to access deep soil-moisture which could be highly saline, rather than when grown in areas of the landscape which are saline and waterlogged in winter.

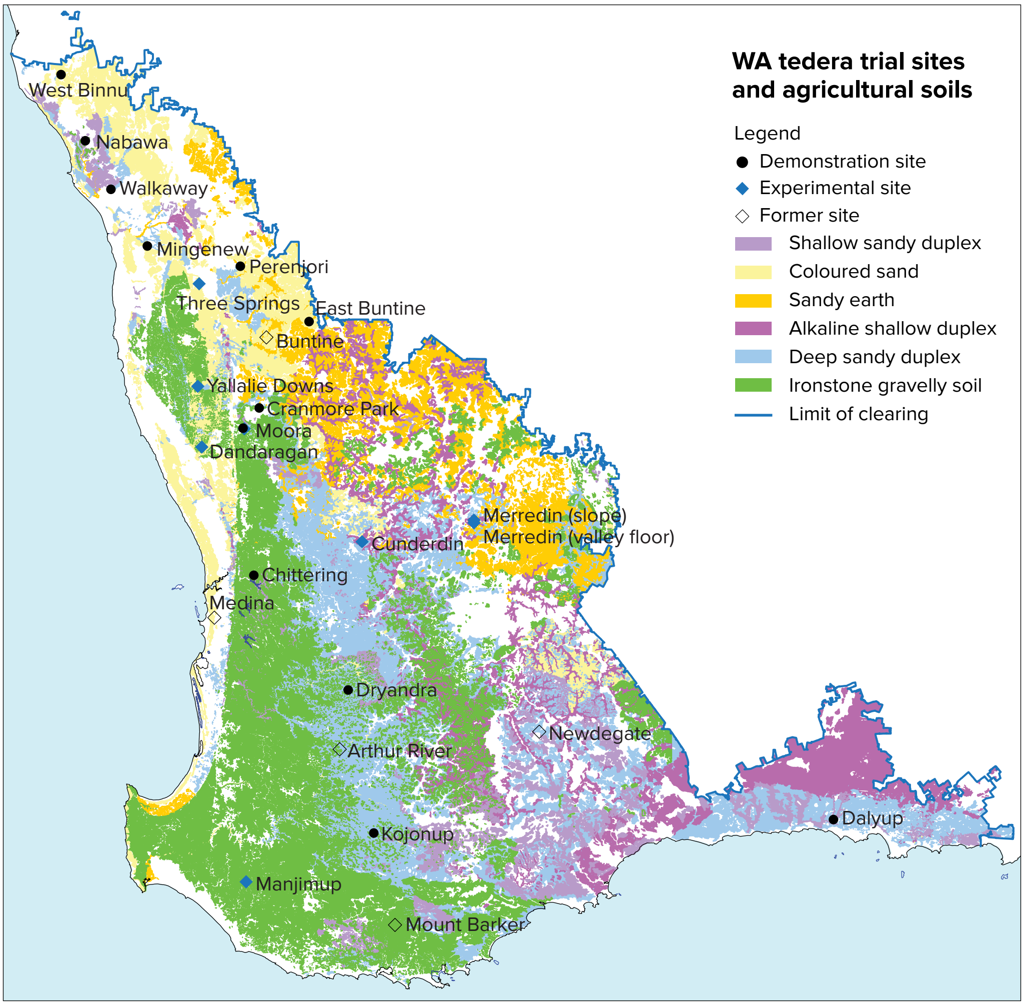


Figure 11. WA's soil types and research locations.

Soil nutrition

- **While tedera can grow successfully in lower nutrient conditions than other legume pastures, test soils as part of planning.**
- **Match tedera with the lowest phosphorus paddocks when planning a pasture investment program.**

What soil nutrients does tedera need?

Extensive glasshouse and field trials have examined the phosphorus (P), potassium (K) and sulphur (S) requirements to establish and maintain tedera production. In many cases, the trials found existing fertility in agricultural soils is likely to support optimal tedera production without additional nutrient input for a period of time.

The reduced requirements for P, K and S at peak production of tedera represent a major advantage over less efficient species, meaning less fertiliser (and reduced input costs) are needed to maximise tedera biomass production.

Soil or shoot testing will identify when further nutrients are required. Producers can also use the information from these trials to help with paddock selection for growing tedera and ongoing fertiliser budgeting (see Table 1).

Here's what was learned in the trials

Tedera performs well in low P soils

Research investigated the response of tedera and 11 other perennial legumes* to a range of soil P concentrations. Plants were assessed for nodulation response, root morphology and root adaptations to improve soil P acquisition, plant biomass components and shoot P concentration. The results showed tedera:

- was among the best performers in low-P environments
- had excellent P-response efficiency and it required the least amount of P to get a response (due to its larger seed size providing more reserves for the developing seedling)
- had the longest root length
- grew more and larger nodules than most other species in the treatment at all rates of P.

Tedera is an efficient user of K and S

Research compared the P, K and S requirements of tedera to sub-clover. The soil had a baseline K level of 20mg/kg Colwell K and 3.5mg/kg S, 5mg/kg Colwell P and a pH of 4.4. The results showed the following:

- Tedera was identical to sub-clover in yield responses when between 0 and 50mg/kg P was added to a highly deficient soil (never fertilised soil in native vegetation area), and 90% of the maximum yield was achieved with the addition of approximately 28mg/kg P in both species.
- Tedera needed less K to attain 90% of maximum yield. The difference was substantial, with sub-clover needing 93.6mg/kg K added to soil and tedera needing 38.8mg/kg.
- Tedera had a low S requirement. Despite being considered nutrient deficient in an agricultural context, the field soil used was high enough in S (3.5mg/kg) for maximum production of tedera. In contrast, sub-clover had a higher requirement for S, showing a response to the addition of 1.2 and 2.4mg/kg S.

A nutrient response experiment tested the biomass response of tedera and lucerne to 10 different levels each of P, K and S. Two genotypes of tedera (Palma and Lanza®) were grown alongside lucerne cultivar SARDI-Grazer⊕ in a glasshouse. The experiment established critical levels of soil and shoot P, K and S for optimum production. The results showed the following:

- Tedera was more P, K and S-efficient than lucerne.
- Tedera was able to reach peak productivity with lower Colwell P levels (3–19mg/kg for Lanza® and 5–27mg/kg for Palma), compared to lucerne (10–45mg/kg) (Figure 12).
- Lanza® reached peak productivity with soil K concentrations around half that of lucerne, and tedera Palma did not show a strong shoot biomass response to Colwell K ($P = 0.25$) (Figure 13). This was in soil with a Colwell K level of <15.
- Tedera was relatively efficient at low levels of soil S, with small responses over an order of magnitude of soil S concentrations between 1.3 and 13mg/kg (Figure 14). In the glasshouse experiment, adding between 0 and 16mg/kg S to soil which contained around 1.5mg/kg S did not lead to strong biomass responses in either tedera, but lucerne did respond strongly.

The critical nutrient concentrations in soil and shoots to provide 90% of peak productivity and the levels at which peak productivity occurred are provided in Table 1.

The soil nutrient concentrations identified here should be read in the context of the soil type used which was a highly leaching soil type with little buffering capacity (phosphorus buffering index (PBI) = 2.5).

* *Lotus australis, Cullen australasicum, Medicago sativa, Lotononis bainesii, Kennedia prorepens, Kennedia prostrata, Glycine canescens, Cullen tenax, Bituminaria bituminosa, Lotus corniculatus* and *Macroptilium bracteatum*.

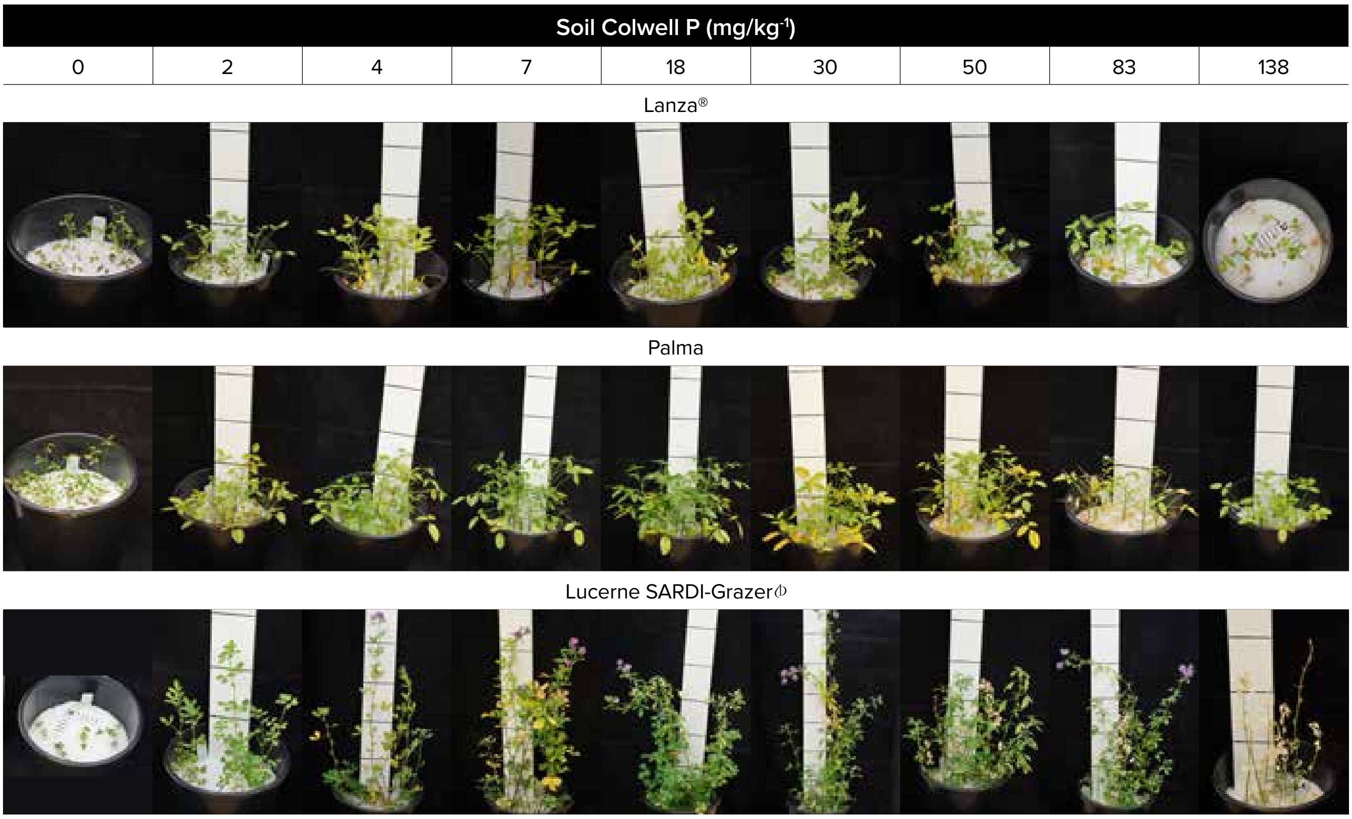


Figure 12. Pots containing 12-week-old Lanza®, tedera Palma and lucerne grown in the glasshouse with differing levels of soil Colwell P. Black lines on large scale bars are 10cm intervals. Photos courtesy Dr Richard Bennett.

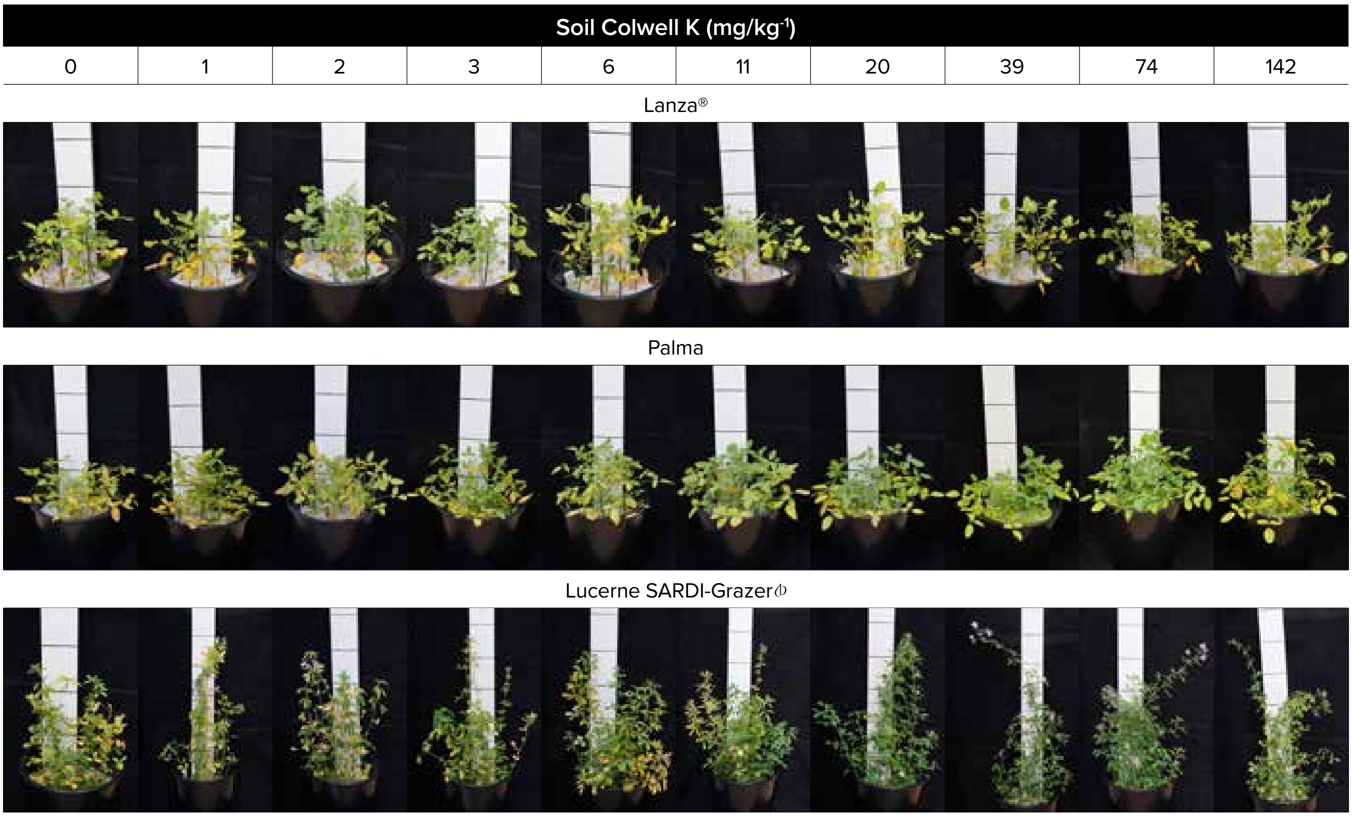


Figure 13. Pots containing 12-week-old Lanza®, tedera Palma and lucerne grown in the glasshouse with differing levels of soil Colwell K. Black lines on large scale bars are 10cm intervals. Photos courtesy Dr Richard Bennett.

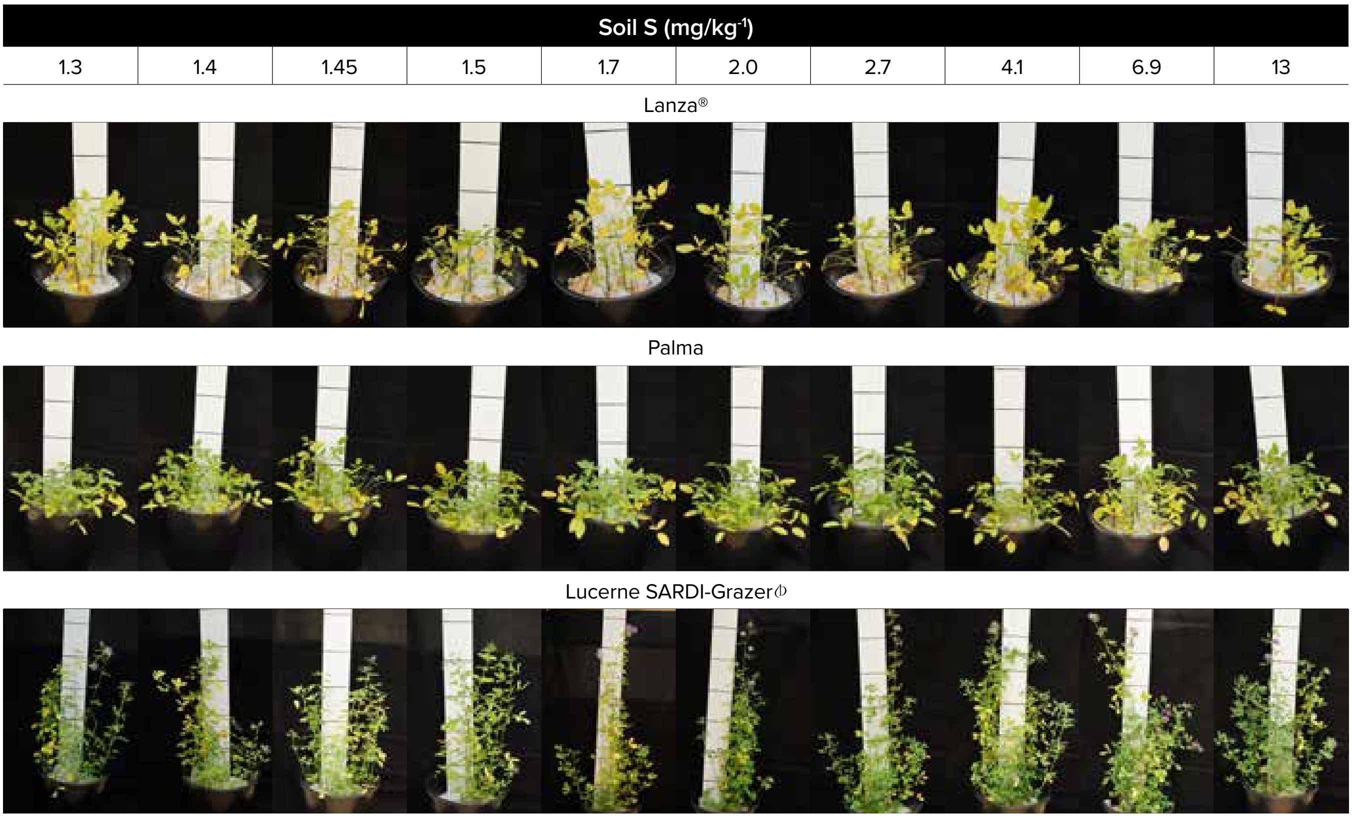


Figure 14. Pots containing 12-week-old Lanza®, tedera Palma and lucerne grown in the glasshouse with differing levels of soil S. Black lines on large scale bars are 10cm intervals. Photos courtesy Dr Richard Bennett.

DID YOU KNOW

Tedera has lower soil nutritional needs than other pastures, such as sub-clover and lucerne, for both establishment and production. This means producers can:

- have the flexibility to select lower fertility paddocks for tedera planting
- reduce the costs of establishment and production
- avoid over-fertilising and reduce the risk of nutrient run-off
- reduce reliance on fertilisers.

TOP TIP

Growers should sample soils prior to sowing to identify the best suited soil types and sample shoot biomass once established for plant nutrient status.

To better understand and manage phosphorus check out MLA's Five Easy Steps P tool. The tool helps you understand the PBI and calculate the correct P requirements. Find it at: etools.mla.com.au/hub/

Table 1. P, K and S nutrient concentrations in soils (mg/kg) and shoots (%) which produced greater than 90% of peak biomass. Measurements outside these figures could indicate deficiency or toxicity. Lower 90% is the value where yield starts to be <90% because of suboptimal nutrition. Upper 90% is when yield drops due to excessive nutrition.

	Lanza®			Tedera Palma			Lucerne		
	Lower 90%	Peak	Upper 90%	Lower 90%	Peak	Upper 90%	Lower 90%	Peak	Upper 90%
Colwell soil P	3.0	7.6	19	5.5	12	26.6	10	22	46
Shoot P	0.06	0.48	0.98	0.19	0.52	0.99	0.24	0.74	1.5
Colwell soil K	3.0	12	50	NS	NS	NS	6.0	27	120
Shoot K	0.50	1.36	3.1	NS	NS	NS	0.31	1.3	3.4
Soil S	7.4	12*	No max	NS	NS	NS	3.8	8.8	20**
Shoot S	0.22	0.25*	No max	NS	NS	NS	0.12	0.23	0.39**

* Peak productivity was not reached within the soil nutrient concentrations tested (no max) and so the peak productivity level is taken as the maximum productivity. ** These figures are extrapolated from beyond the range of tested soil S concentrations.
NS (no significance).

The impact of nutrients on nodulation

One of the benefits of growing pasture legumes is the ability for the plant to supply nitrogen (N) via the root nodulation process and tedera is no different. However, soil P, K and S levels impact on the nodulation process.

The largest reductions in effective nodulation were seen where P levels were either low or high, and this was consistent among the three genotypes studied. Research also demonstrated tedera nodulation could be detrimentally affected by extremes in soil P and speculated the causes could relate to high demand for P in nodules or reduced carbohydrate supply to nodules due to P deficiency or toxicity affecting shoot growth.

Results also showed evidence of soil K or S levels affecting nodulation in tedera. For Lanza®, marked decreases in nodulation were seen at low and high Colwell K, and some detrimental effect at low soil S levels (see Figure 15). Reduced nodulation at high K was seen in tedera Palma.

The impact of soil pH on rhizobium strain survival was tested during research and the range for optimal survival was between pH 5 and pH 7.5 (although some grew at pH 8.5). No strains grew at 300mM NaCl (millimolar sodium chloride).

The impact of soil acidity on nodulation was not tested.

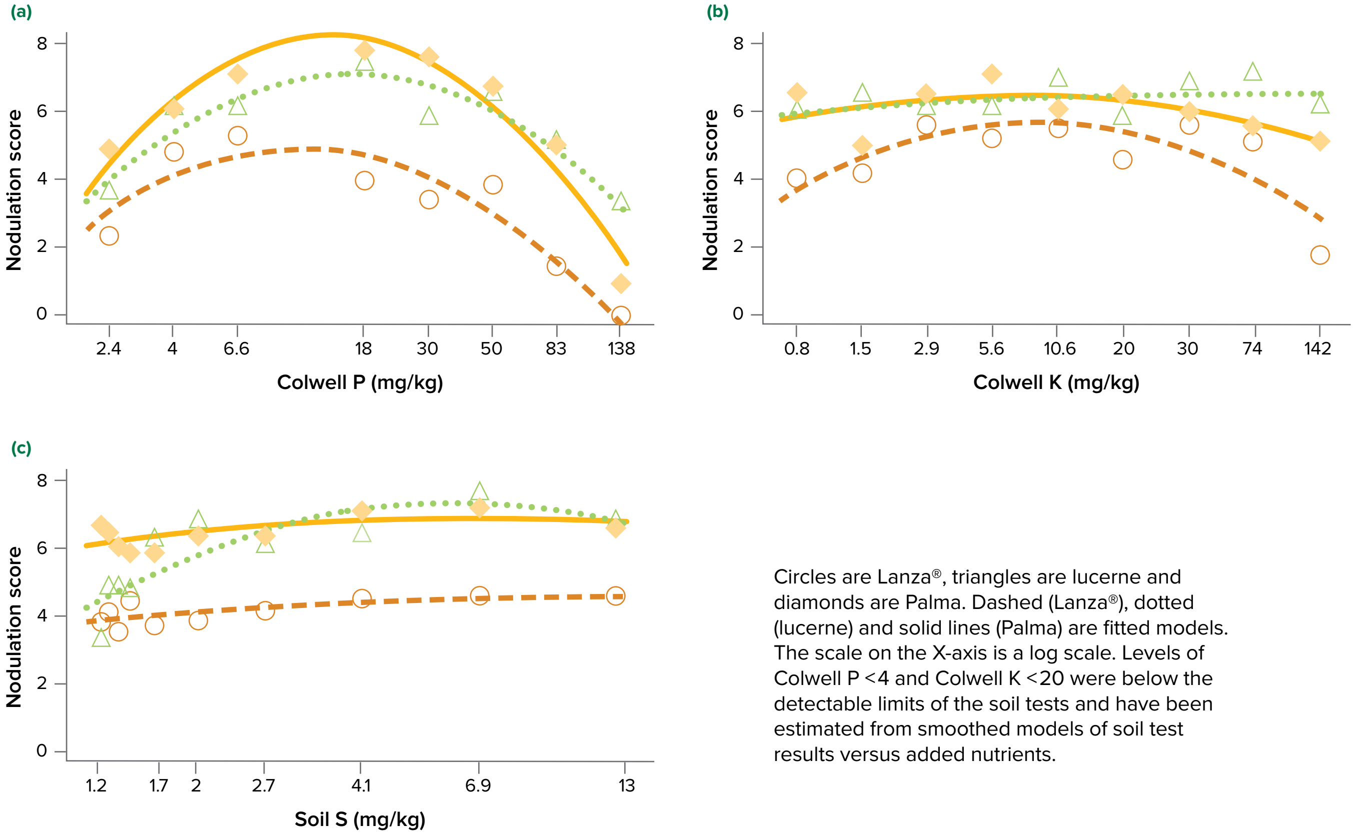
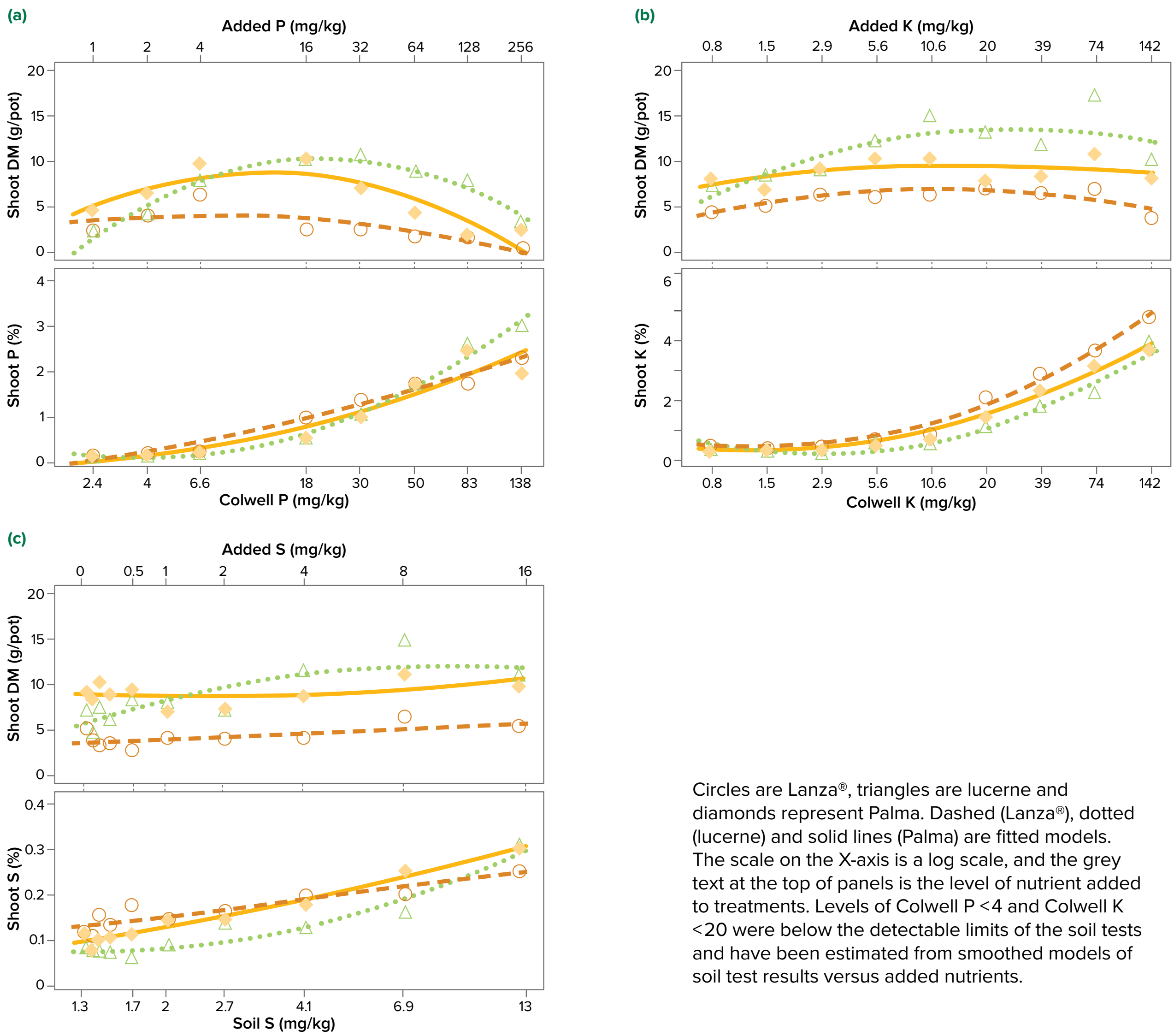


Figure 15. Nodulation score in response to increasing levels of (a) Colwell P, (b) Colwell K or (c) soil S. Nodulation scores: 0 = absent, 0.5 = ineffective, 1 = rare, 2 = scarce, 3 = moderate, 4 = adequate 5 = ample, 6 = abundant, 7 = very abundant and 8 = extremely abundant.

TOP TIP

Watch out for K

Growers need to be mindful of the strong detrimental effects of high K on tedera nodulation.



Circles are Lanza®, triangles are lucerne and diamonds represent Palma. Dashed (Lanza®), dotted (lucerne) and solid lines (Palma) are fitted models. The scale on the X-axis is a log scale, and the grey text at the top of panels is the level of nutrient added to treatments. Levels of Colwell P <4 and Colwell K <20 were below the detectable limits of the soil tests and have been estimated from smoothed models of soil test results versus added nutrients.

Figure 16. Shoot biomass response (grams/pot) and shoot P, K or S concentration (%) in response to increasing levels of (a) Colwell P (b) Colwell K or (c) soil S.

Spotting signs of too many or too few nutrients in tedera plants

Phosphorus deficiency

P deficiency in tedera is expressed as a combination of several characteristics. First, leaf margins develop dark necrotic lesions surrounded by a small ring of pale yellow or yellow-white colouring (chlorosis) (Figure 17A, B and D). Second, some leaves develop widespread mottling with a purple hue (Figure 17D). Third, leaf size is markedly reduced, compared to healthy leaves (Figure 17C and F). In trials, P deficiency damage to leaf margins did not include bleaching. P-deficient plants dropped old leaves once severely affected.

Overall, seedlings growing under extreme P deficiency fail to grow beyond a few leaves, although plants did survive to the end of the experiments (Figure 17). Lucerne also expressed marginal necrosis (dark brown) and marginal chlorosis in low P treatments.

Phosphorus toxicity

P toxicity symptoms in tedera were consistent among the two genotypes (Figure 18) and, as severity increased, the symptoms progressed through obvious inter-vein chlorosis, bleaching on the leaf margins (Figure 18A and C), extensive bleaching across the entire lamina, and leaf drop which left the petioles attached to stems (Figure 18B). In extreme cases, the growing tips of plants were killed and the entire plants died. The lightly coloured bleaching symptoms were distinct from P deficiency and K imbalance in the lack of dark necrotic lesions or margins.

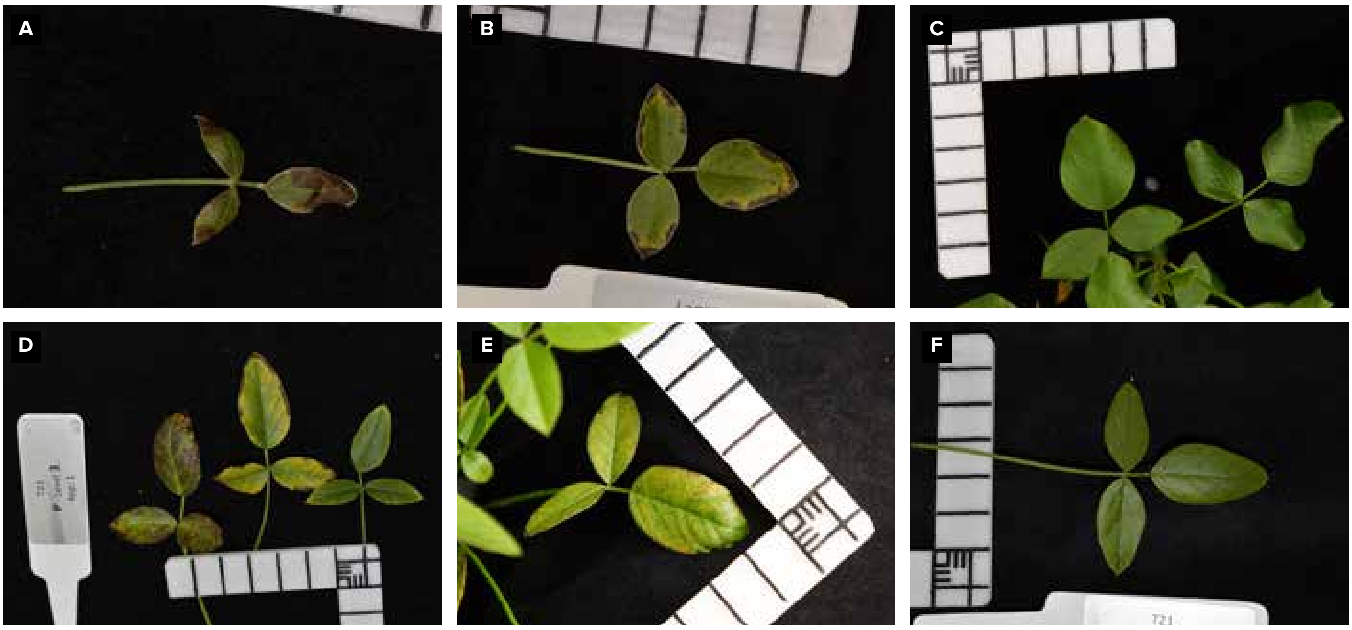


Figure 17. Leaves taken from Lanza® tedera (A, B, C) and Palma (D, E, F) grown in soils with deficient levels of phosphorus (A, B, D, E) and adequate phosphorus (C, F). Symptom progression from younger to older leaves (R to L) is shown in image D.
Photos courtesy Dr Richard Bennett.

Figure 18. Leaves taken from Lanza® tedera (A) whole Lanza® plants (B) and Palma (C, D) grown in soils with toxic levels of soil phosphorus (80mg/kg Colwell P). Photos courtesy Dr Richard Bennett.

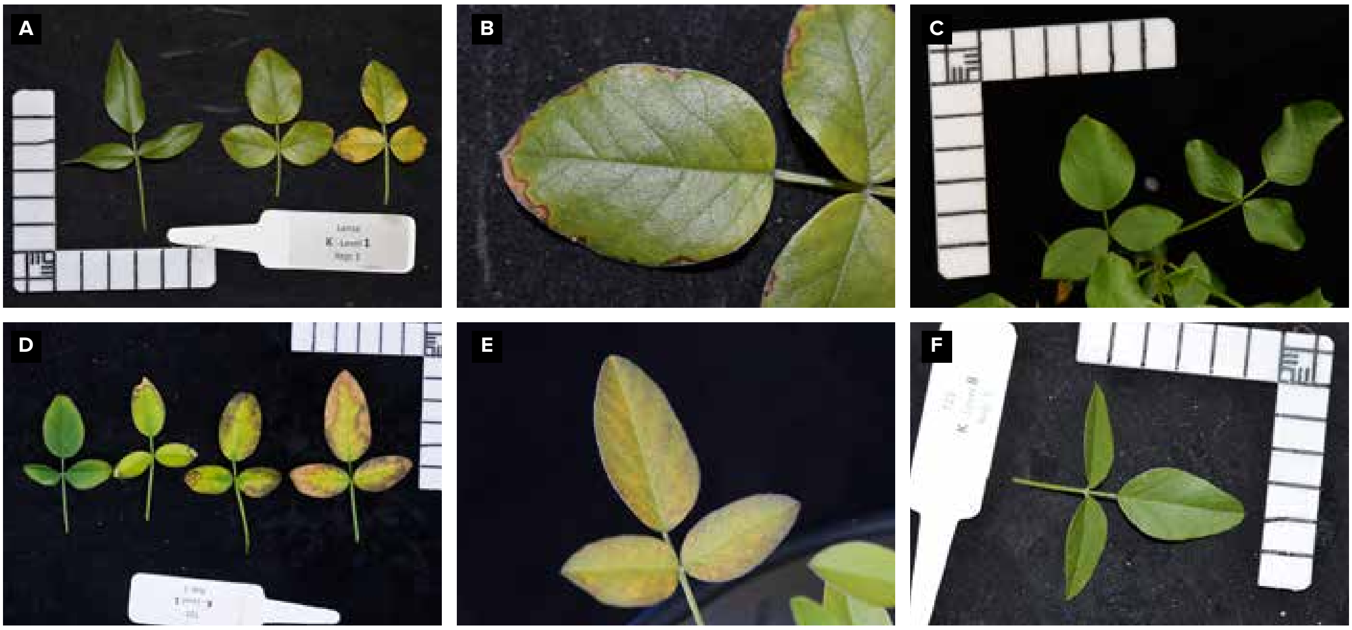


Figure 19. Leaves taken from Lanza® tedera (A, B, C) and Palma (D, E, F) grown in soils with deficient levels of potassium (A, B, D, E) and adequate potassium (C, F). Symptom progression from younger to older leaves (L to R) are shown in images A and D.
Photos courtesy Dr Richard Bennett.

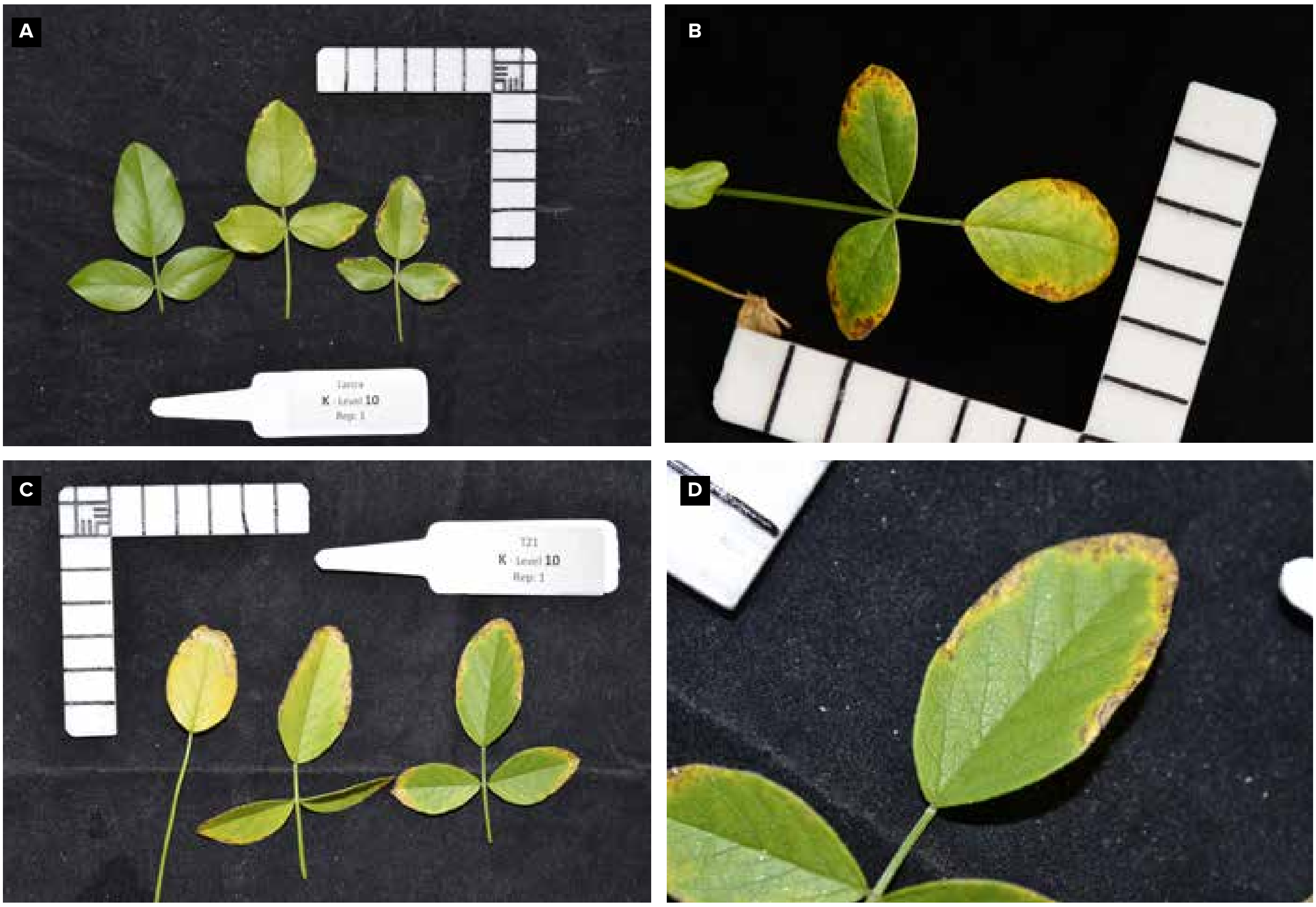


Figure 20. Leaf symptoms of potassium toxicity in Lanza® tedera (A, B) and Palma (C, D). Photos courtesy Dr Richard Bennett.

Potassium deficiency

In both tedera genotypes, leaves presented with marginal necrosis and bleaching in response to low soil K (<1.5mg/kg), with a dark margin between heathy and damaged tissue (Figure 19A, B and D). In Lanza®, the damaged tissue had a distinct transition to undamaged tissue, but the margins between healthy and damaged tissue in tedera Palma were less distinct, and some leaves had widespread dark spots (Figure 19E). Leaves also showed general yellowing across the lamina in both species. As expected, the deficiency symptoms were most severe in older leaves, with youngest leaves barely affected. Compared to healthy leaves (Figure 19C and F), K deficiency did not appear to affect leaf size, in contrast to the deficiency symptoms seen for P. As symptoms progressed, old leaves became completely necrotic and dropped readily.

Potassium toxicity

Tedera leaves displayed marginal necrosis in response to high levels of K (~150mg/kg Colwell K). However, in contrast to K deficiency, K toxicity symptoms included a distinct ring of chlorosis around the necrotic margins (Figure 20B and D), and the widespread spotting seen in tedera Palma due to K deficiency was not seen under toxicity conditions. Symptoms of K toxicity were more pronounced in older leaves (Figure 20A and C), likely due to accumulation of toxic K levels over time, and leaves dropped readily once badly affected.

Sulphur deficiency

S deficiency expressed in all genotypes as uniform chlorosis across the entire leaf lamina (Figure 21A and B), with mild black spotting and necrotic lesions in the worst cases (Figure 21B). S deficiency symptoms can be confused with N deficiency, however, in this experiment, S deficiency (<2mg/kg S) led to more uniform chlorosis across the leaf (not inter-vein) and across the plant as growing tips were affected (Figure 21C and D).

Figure 21. Leaf and whole plant symptoms of Lanza® tedera (A, C) and Palma (B, D) grown in soils with low sulphur (<2mg/kg). Photos were taken at 12 weeks growth except image D, taken at eight weeks. Photos courtesy Dr Richard Bennett.

Testing nutrients in the field experiments

Experiments tested the response of tedera to K and P at field sites in Cunderdin, Dandaragan and Three Springs, WA.

Fertiliser was applied at sowing and four weeks following sowing with seven levels of P (0, 5, 10, 15, 20, 25 and 30kg/ha), seven levels of K (0, 5, 10, 20, 40, 60 and 80kg/ha) and two treatments with P and K at medium (P 15 + K 20) and high level (P 30 + K 80). Rainfall during the field trials was much lower than the 30-year average, with total rainfall and rainfall percentiles from sowing in mid-2017 up to end of June 2020 for each site being: Dandaragan 1,450mm and 2%, Three Springs 900mm and 4%, and Cunderdin 850mm and 11%.

Key findings included:

- There was no strong biomass response from tedera when up to 80kg/ha of K was added to any of the three field sites. This may reflect the relatively high Colwell K status of the soils prior to nutrient addition, with the sites containing 47–291mg/kg Colwell K in the topsoil, along with Colwell K levels from 18–414mg/kg in the subsoil (Table 2). These values are all in excess of the Colwell K concentrations at which peak productivity occurred for Lanza® in glasshouse experiments.
- The response to P at Dandaragan was significant for the cumulative growing season cuts (July and October) in 2018 ($P = 0.027$) and 2019 ($P = 0.009$) (Figure 22). Modelling indicated growing season productivity in both years in the absence of added P was similar at just over 1.5t/ha, and the addition of P raised productivity by more then 900kg/ha in 2018 and more then 500kg/ha in 2019, up to a maximum of about 2.5t/ha in 2018 and 2.1t/ha in 2019.
- The productivity benefit of added P at Dandaragan was only observed during the cooler, wetter growing seasons, whereas no benefit was seen at Cunderdin, Three Springs, or at Dandaragan during the warmer and drier seasons when high temperatures and moisture stress were limiting growth. Dandaragan received more than 1.6 times the rainfall of Three Springs or Cunderdin, and productivity at this site was, therefore, substantially higher.
- The different responses to P at the three sites were not explained by initial P concentrations in the soil, as all sites had relatively similar levels of Colwell P (22–30mg/kg in topsoil and 6–18mg/kg in subsoil), with the lowest P occurring at Cunderdin. Instead, it is likely that the difference in sites was best explained by rainfall over the cooler wetter months, received at Dandaragan but not Cunderdin or Three Springs.

Table 2. Soil analysis for Dandaragan, Three Springs and Cunderdin fertiliser response experiment sites.

	Dandaragan	Three Springs	Cunderdin	Dandaragan	Three Springs	Cunderdin
Soil type	**Sandy loam**	**Loamy sand**	**Loam**	**Sandy loam**	**Loamy sand**	**Loam**
		0–10cm			**11–30cm**	
Soil pH ($CaCl_2$)	6.8	5.4	7.6	5.1	5.2	5.7
EC (dS/m)	0.143	0.225	0.139	0.040	0.230	0.073
Organic C (%)	2.03	0.75	1.45	0.77	0.48	1.38
NO_3 (mg/kg)	36	8	10	7	5	19
NH_4 (mg/kg)	3	1	0	0	0	2
Colwell P (mg/kg)	30	35	22	11	18	6
PBI	19	23	120	26	20	49
Colwell K (mg/kg)	47	170	291	18	247	414
S (mg/kg) KCl 40	12	19	23	16	17	15

Soil pH (acidity), EC (electrical conductivity measured as deciSiemens per metre), organic C (organic carbon), NO_3 (nitrate measured as milligram per kilogram), NH_4 (ammonium), Colwell P (phosphorus), PBI (phosphorus buffering index), Colwell K (potassium) and S (sulphur).

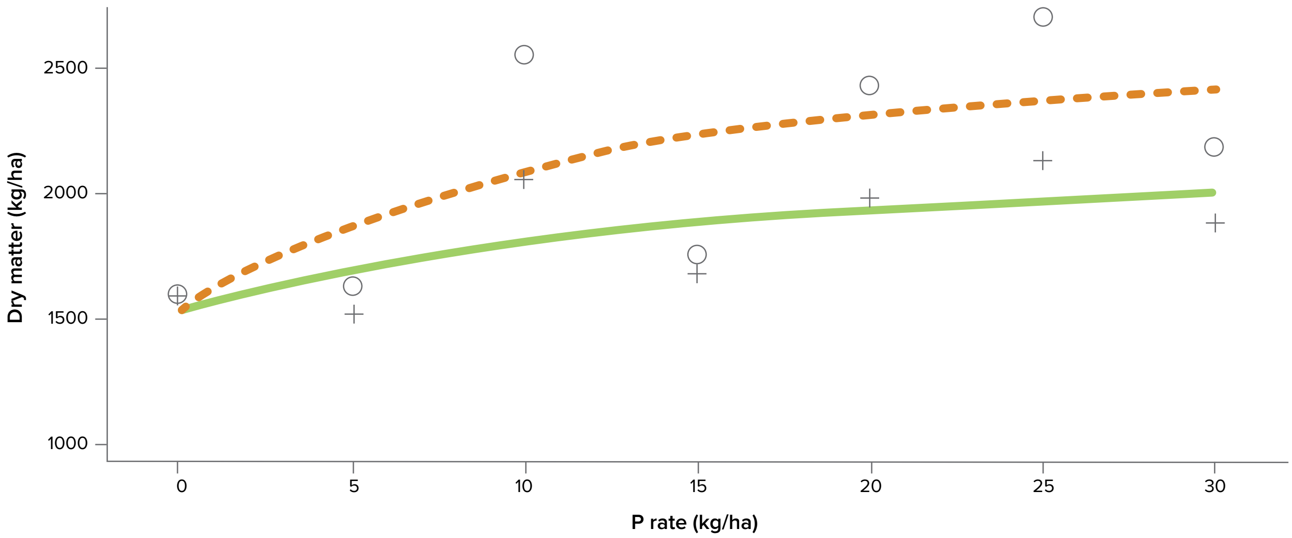


Figure 22. Lanza® tedera shoot biomass response (kg DM/ha) to P application over two growing seasons (cumulative biomass above 5cm from July and October cuts) at Dandaragan. 2018 data is open circles and dotted line, and 2019 data is crosses and solid line.

What about aluminium and manganese?

Aluminium (Al) and manganese (Mn) toxicity constrain plant growth in some highly acidic agricultural soils in Australia.

Research tested the sensitivity of seedlings of 10 tedera genotypes to toxic levels of Al and Mn in hydroponics, along with 14 genotypes from 10 other species (including several *Trifolium* species, two Lotus species, chicory *(Chichorium intybus)* and lucerne).

Al sensitivity was assessed by measuring depression in root length and Mn sensitivity was assessed by measuring depression in shoot weight, compared to controls.

The results showed there was a range of tolerance expressed by tedera to Al and tedera was overall very tolerant to Mn, offering potential for future breeding and selection to adapt cultivars to acid soils with these constraints. Overall, tedera had moderate tolerance to Al, compared to other species and genotypes, with *Lotus pedunculatus, L. corniculatus*, chicory, *Trifolium repens* and *T. tumens* all less affected than tedera.

However, the best performing tedera accession was better than *T. ambiguum, T. pratense, T. fragiferum* and lucerne.

Tedera expressed consistently high Mn tolerance, with the 10 tedera accessions ranked among the top 11 of the 24 genotypes and species tested (one *L. corniculatus* accession was ranked three). For comparison, lucerne ranked last in Mn tolerance.

TOP TIP

Tedera is well placed among the common pasture legumes for tolerance to Al and Mn toxicities encountered in acid soils, and there is potential for selection to improve tolerance to Al.

Section 2. Managing the seed bank

Maximising germination

- Tedera is a hard-seeded species which means germination will only occur after a period of rainfall, not single false break events.
- The hard seededness also means once sown, tedera will regenerate itself – particularly after extended dry seasons as seeds may sit dormant in the ground for some time awaiting a triggering rainfall event.

False breaks of season are a threat to successful establishment of pastures from seed banks in Mediterranean-like climates.

Successful pasture species usually have a degree of hard seededness to ensure against the germination of a large proportion of the seed bank in a single rainfall event. Experiments explored the hard seed breakdown of tedera in the summer and autumn and its susceptibility to false breaks.

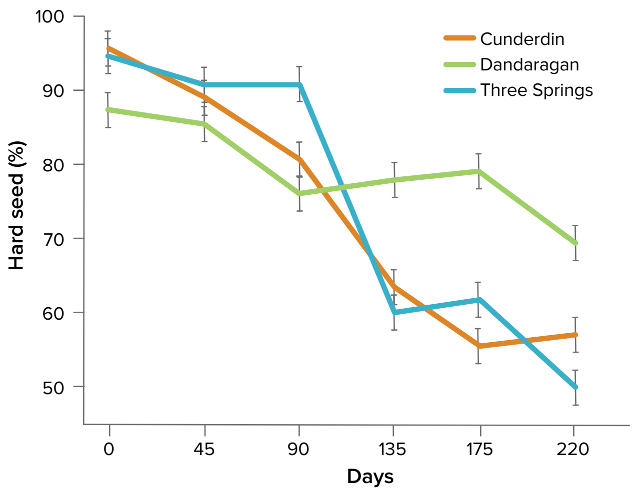


Figure 23. Percentage of hard seed from zero to 220 days for each site. Day 0 is the beginning of summer.

Newly ripened seeds of Lanza® tedera were hand-harvested from mature plants growing at Cunderdin, Dandaragan and Three Springs in 2018 and from Dandaragan again in 2019.

Across all experiments, less than 65% of seed had softened over the summer and autumn period. While the extent of seed softening varied between sites, a general pattern emerged with slow initial softening, accelerating during early autumn (March–April), and then slowing into late autumn/winter. Such a pattern, and the remaining hard seed, would offer some protection against false breaks of season.

The three sites did not perform in the same way. The percentage of hard seeds for each site from day 0–220 is presented in Figure 23. Seed lots from Three Springs and Cunderdin had a higher percentage of initial hard seed (95%) than Dandaragan (88%), but seed softening was faster and both sites finished with a lower percentage of hard seed in June (50–70%).

Table 3. Monthly rainfall, maximum and minimum temperatures at Three Springs, Cunderdin and Dandaragan during seed softening experiments.

	Three Springs 2018/19			Cunderdin 2018/19			Dandaragan 2018/19			Dandaragan 2019/20		
	Rainfall (mm)	Max. temp. (°C)	Min. temp. (°C)	Rainfall (mm)	Max. temp. (°C)	Min. temp. (°C)	Rainfall (mm)	Max. temp. (°C)	Min. temp. (°C)	Rainfall (mm)	Max. temp. (°C)	Min. temp. (°C)
December	1	41.8	11.5	2.4	41.2	6.7	5.4	41.7	10	1.2	43.1	9.3
January	0.2	44.4	12.3	0	44.3	11.3	2	44.2	11.6	1.0	43.8	10.3
February	0	42.9	11.5	0.4	42.9	11.3	0.2	42.0	12.2	84.2	42.6	13.6
March	5.4	39.4	12.9	1.6	39.1	9.7	1.2	38.4	11.5	0.0	37.9	11.3
April	4.4	37.3	3.5	21.6	37.5	3	16.6	37.4	5.1	0.0	38.3	8.6
May	0.4	30.6	0	7.6	29.5	-0.8	4.6	30.4	-0.3	32.8	29.9	4.5
June	114.2	25.8	1.7	67.6	23.5	0.2	138.0	25.7	4	63.0	27.5	6.4

Seedling recruitment

The ability of tedera to recruit from seed within a sward is an important attribute. While vegetative propagation can be taken for granted in perennial grass forages, recruitment from seed in lucerne is rare.

At Cunderdin, a site located in the valley floor with a heavy clay soil, researchers observed widespread death of adult tedera plants in the summer of 2019–20 due to dry conditions. From 25–29 February 2020, 72mm of out-of-season rainfall prompted widespread germination and re-establishment of tedera across the whole area (Figure 24 left). This rainfall event proved to be a false break as little rainfall followed until the end of May, but the drought tolerance of tedera seedlings enabled survival through the false break and it successfully regenerated (Figure 24 right).

The whole site was regenerated by seedlings indicating long-term perennialism can be achieved with sward regeneration in tedera. This site set seed in the establishment year in December 2017 but after this time, defoliation management treatments were imposed and no seed set occurred. Therefore, seedlings which regenerated the site came from a seed bank which remained viable in the soil since December 2017 and re-established the site, germinating in early March 2020.

The recruitment effect is also noticeable in seed crops where many seeds fall to the ground every year. For example, a seed crop established at Dandaragan in 2017 had seed sown in two out of every three rows, as clearly seen in March 2018 (Figure 25). Three years later, the skipped rows in the same seed crop are no longer clearly visible due to regeneration (Figure 26).

Figure 24. Cunderdin field site on 27 March 2020 (left) and 27 July 2020 (right) with seedlings growing across the whole site as a result of late-February rainfall. Photos courtesy Daniel Real.

Figure 25. 2017 seed crop at Dandaragan on 22 March 2018, with skipped rows clearly visible. Photo courtesy Daniel Real.

Figure 26. 2017 seed crop at Dandaragan on 24 March 2021, with skipped rows obscured by seedling regeneration.
Photo courtesy Daniel Real.

Section 3. Planting tedera

Checklist for sowing

- ☑ Ensure you are sowing into a clean paddock (preferably a cropping paddock) with good weed control for several years leading up to sowing.
- ☑ Carry out one or two herbicide knockdowns using glyphosate to minimise weed competition at establishment.
- ☑ Source high quality seed and determine fertiliser requirements based on soil test results.
- ☑ If sowing in a new area, ensure seed is inoculated with the correct strain of rhizobia.
- ☑ If insect infestation is identified as a risk, apply an insecticide with one of the herbicide applications.
- ☑ Use standard seeding equipment to sow the pasture.
- ☑ Sow at 2cm depth at rates of 10–15kg/ha at 22cm row spacing for highest productivity.
- ☑ Sow after the first rains of the season break to allow seedlings to develop a deep root system before the first summer.
- ☑ Aim for 16 plants/m^2 for optimal establishment.

Seed quality

Tedera seed is encased in a pod which the seed needs to germinate 'through' after sowing. A threshing process is required to 'scarify' the seeds and this results in germination rates of 50–70%. Germination rates are generally lower than other pasture species. This is due to:

- the pericarp or pod being inseparable from the seed, meaning scarification is not uniform
- tedera's long flowering window (from September to December) which means seed maturity is over a long period. When harvesting tedera for seed, the most suitable technique is to spray-top the pasture with a desiccant herbicide at peak (80%) seed maturity and then harvest with a combine harvester.

It is risky to leave crops to mature fully as mature pods can be easily knocked from flowers under windy or stormy conditions.

Seed inoculation

Tedera must be inoculated to biologically fix nitrogen. Seed should be sown soon after inoculation (within 24 hours).

The root-nodule bacteria which establishes symbiosis with tedera is *Mesorhizobium ciceri*. This specific strain is not found in soils tested in Australia.

The special strain WSM 4083 was developed for tedera by Murdoch University's Centre for Rhizobium Studies and peat inoculant is commercially produced by BASF. WSM 4083 is suited to pH 4.8–8.5, salinity levels less than 300mM NaCl and temperatures between 15 and 35°C. Another strain, WSM 4127, is recommended as a back-up strain.

Figure 27. Close-up of tedera nodules (top); nodulated seedling (bottom). Photos courtesy Daniel Real.

Figure 28. Time-of-sowing experiment at Dandaragan on 10 December 2018 demonstrating clear differences in plant size and vigour among sowing dates. Three time-of-sowing experiments were established at Dandaragan, Three Springs and Cunderdin with four sowing times: dry sowing before the break of season (15 April), early sowing just after the break of season (15 May), late sowing after cereal crop program was completed (1 July) and early spring sowing (15 August). Photo courtesy Daniel Real.

Time of sowing

Sowing as early as possible after the first autumn/winter rains is recommended in areas with mild winters and low rainfall to strike a balance between allowing plants to germinate well while providing time for seedlings to develop a deep root system before the first summer. In regions with medium to high rainfall and cold winters (Figure 28), early spring planting is possible, provided there is good control of winter volunteer species.

The sowing date which achieved the best germination in the first year was the early winter sowing (1 July). At this time of the year, about 45 days after the start of the rainy season, seeds can generally be sown into a wet soil profile.

It is recommended to sow after one or two knockdowns with glyphosate to control the weeds as much as possible, in paddocks with high weed seed banks.

The survival percentage over the first summer (plants surviving in the winter of the second year compared to plants germinated in spring of the first year) showed the early sowing of April and May achieved the best survival during the dry season.

Sowing depth

Field trials and glasshouse experiments established sowing at a depth of 2cm provided the most consistent (Figure 29) and rapid emergence in a range of soil types.

Results also confirmed sowing depth is less critical on sandy soils, and deeper sowing on light soils may provide some protection from lengthy dry spells following sowing (however 2cm is generally recommended).

Sowing technique

Tedera sowing does not require any special equipment and the usual seeding machinery set-up is ideal. All research was done with tyne machines fitted with press wheels. No comparisons of different machines have been undertaken.

Sowing rate

Over all the experimental sites and years of evaluation, sowing rate did not affect the biomass from summer and autumn cuts.

Summer and autumn seasons in the Mediterranean-like climates are the driest seasons, and the biomass production was similar through these dry periods for all sowing rates.

However, during the growing season in winter and spring, when better growing conditions are experienced, the sowing rate of 15kg/ha with higher plant density was able to produce more biomass than the sowing rate of 10kg/ha, and the 10kg/ha also produced more biomass than the sowing rate of 5kg/ha.

It is recommended producers determine the ideal sowing rate – either 15kg or 10kg/ha – based on the price and/or availability of seed.

Row spacing

There were no significant differences in plant counts or emergence percentage based on row spacing at any of the experimental field sites, but productivity was affected by row spacing.

Trials compared spacings of 22, 44 and 66cm at the Cunderdin, Dandaragan and Three Springs sites and, in some seasons, row spacing had little effect on biomass production. However, in drier times the highest production came from 22cm row spacings, leading researchers to recommend this as the optimal spacing.

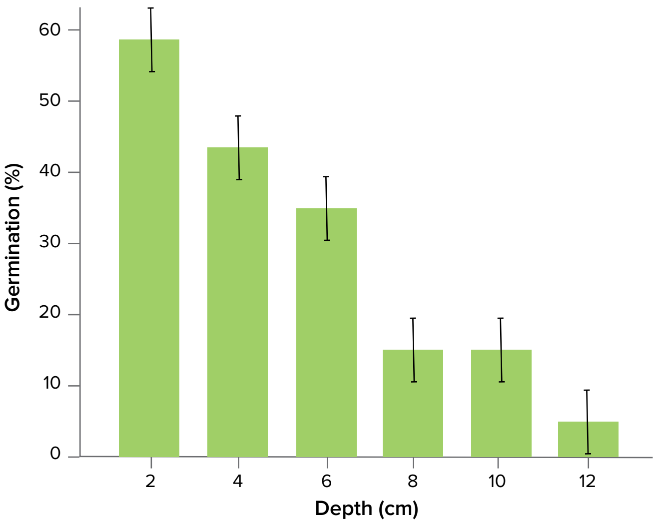


Figure 29. Emergence/germination percentage of tedera seeds after 10 weeks when sown at depth of 2, 4, 6, 8, 10 and 12cm.

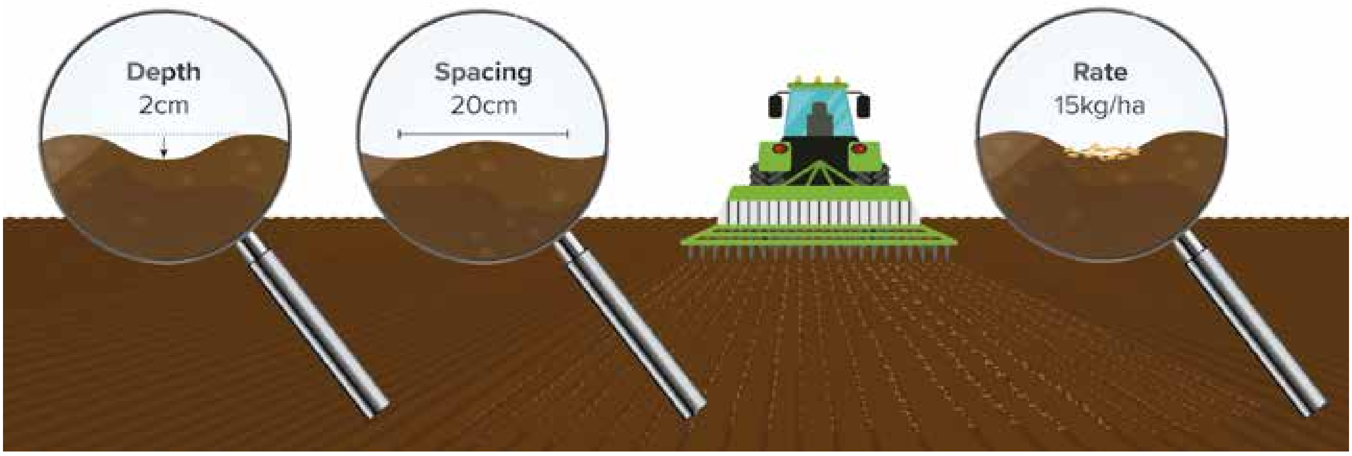


Figure 30. Optimal sowing conditions.

Section 4. Grazing

Grazing management

- **During the establishment year, if tedera is sown early in March/April, it can be grazed for the first time in November/December. If sown in August/September with good growth over summer it could be grazed for the first time in March/April.**
- **Graze tedera frequently during dry periods and allow it to accumulate biomass during cooler, wetter seasons.**
- **Use it to fill the dry period feed gap, as it continues to produce high quality green forage.**
- **Rotationally or continuously graze from late summer, when it can be used to replace supplementary or hand feeding. Fourteen days on and 70 days off works well.**
- **Do not graze tedera below 500kg DM/ha as it will impact future productivity and persistence.**
- **Consider it a tool to extend the grazing window for around three months, allowing annual pastures to rest for seed set and early establishment.**
- **It has been proven safe without any toxicity or photosensitivity issues for sheep and research into cattle consumption of tedera is underway.**
- **Consider it a highly nutritional feed source with high palatability.**

Grazing management

Tedera can remain green during long, dry summers in WA with minimum loss of leaves. The capacity to transfer green feed from one season to another and to reduce feed gaps is one of the most valuable characteristics of tedera.

Here are two options to make optimal use of this out-of-season green feed.

1. **Using tedera to extend the growing season**

   Best practice use of tedera fodder during two critical times of the year is:

   - Period 1 – Late autumn and early winter grazing providing an early start to the green feed season for animals and high quality feed when crops are sown and remaining stubble quality is poor (leached by early rains). This allows producers to rest annual pasture paddocks to improve establishment. Livestock can then be moved onto replenished annual pastures.
   - Period 2 – Late spring, when it is grazed again to extend the green feed season, whilst allowing annual pasture to be rested to maximise seed set and seed bank. The late spring grazing also has the benefit of reducing green leaf area of tedera plants before the stressful summer period, improving sward health and longevity. Animals can then be moved on to stubbles or crop residue following harvest.

   Grazing in period one and two will extend the green growing season by up to three months.

2. **Using tedera to reduce supplementary feeding**

   Defoliation experiments found tedera productivity is maximised by grazing frequently during the drier periods and holding off grazing over the cooler months to support biomass accumulation. This presents a valuable opportunity for growers to use tedera swards to replace or reduce supplementary feeding of livestock, especially late in the dry season when stubbles are of poor quality.

Tedera has previously been shown to persist well under either continuous or rotational grazing over the long term. Continuous grazing of tedera means stocking animals to ensure biomass never gets less than 500kg/ha.

Four grazing experiments were conducted during summer and autumn at Dandaragan (2014–15), Dandaragan (2016), Kojonup (2016) and Kojonup (2017). These experiments demonstrated tedera can maintain or increase sheep live weight and condition, while reducing or eliminating supplementary feeding in summer and autumn using either continuous or rotational (14 days on and 70 days off) grazing. Across the four grazing experiments, tedera pastures supported a stocking rate of 10 sheep/ha with no supplementary feeding during the summer–autumn period.

TOP TIP

Serving it up

Tedera is the solution when all other feed is depleting. There is no recommended grazing start point but if you put sheep on to tedera when, for example, it offers 1,000kg/ha of dry matter then sheep should be removed when that volume is halved (500kg/ha). Grazing to a residual of 500kg/ha is recommended irrespective of the amount at the commencement of the grazing.

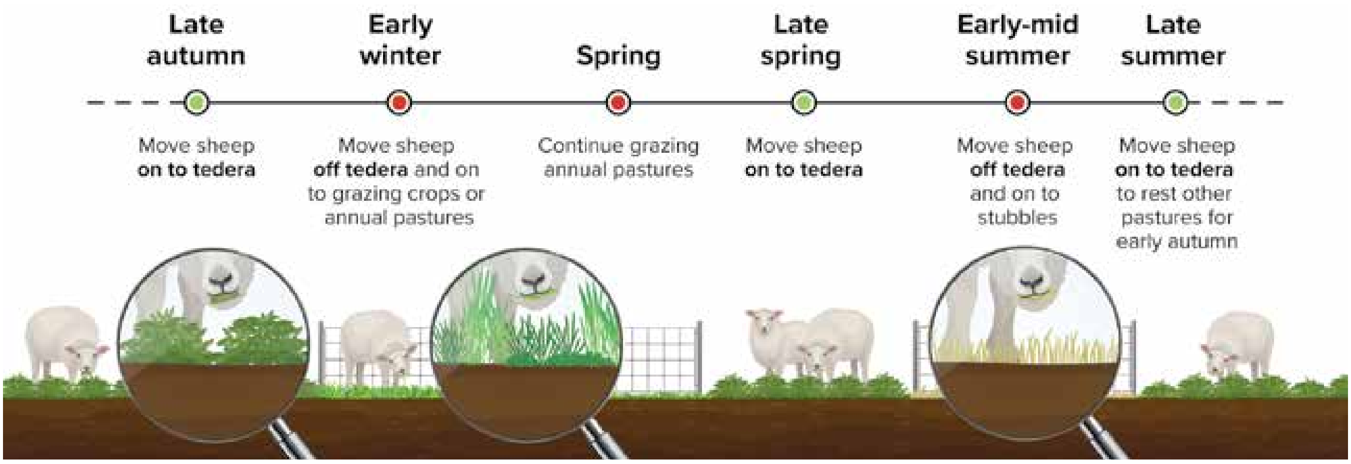


Figure 31. Tedera grazing calendar in mixed farming operation.

All sheep at least maintained live weight and had ideal condition scores around CS3 (Figure 32). Generally, sheep in continuously grazed treatments performed as well as sheep in rotationally grazed treatments, however, some trials found rotational grazing extended the duration of maintenance-level feeding.

However, at Dandaragan in 2014–15, rotational grazing extended the duration of maintenance feeding by 28 days to late April, due to more dry matter.

What is the nutritional value of tedera?

Both leaves and stem material of tedera provide a valuable source of high quality and palatable feed, with good digestibility, protein and metabolisable energy. In contrast to some other perennial legume forages, tedera does not appear to cause bloating possibly due, in part, to a moderate protein level and, in part, to the production of polyphenolics at about 2% and condensed tannins at about 0.5%. No toxicity for grazing animals has been reported for tedera and it is readily accepted by animals after a brief period of adaptation.

The average nutritional value of seven accessions of tedera for each season of the year is presented in Table 4. Crude protein (CP) % peaks in spring and autumn, while dry matter digestibility (DMD) and metabolisable energy (ME) are highest in winter and summer.

In WA, the *in vivo* digestibility of green tedera was assessed by offering it to adult Merino wethers as a sole diet for 42 days as fresh-cut mixed bunches of 20 different accessions. Digestibility was also 60%, equivalent to good quality lucerne chaff used as control diet. Meat quality of animals fed with tedera or lucerne chaff were the same.

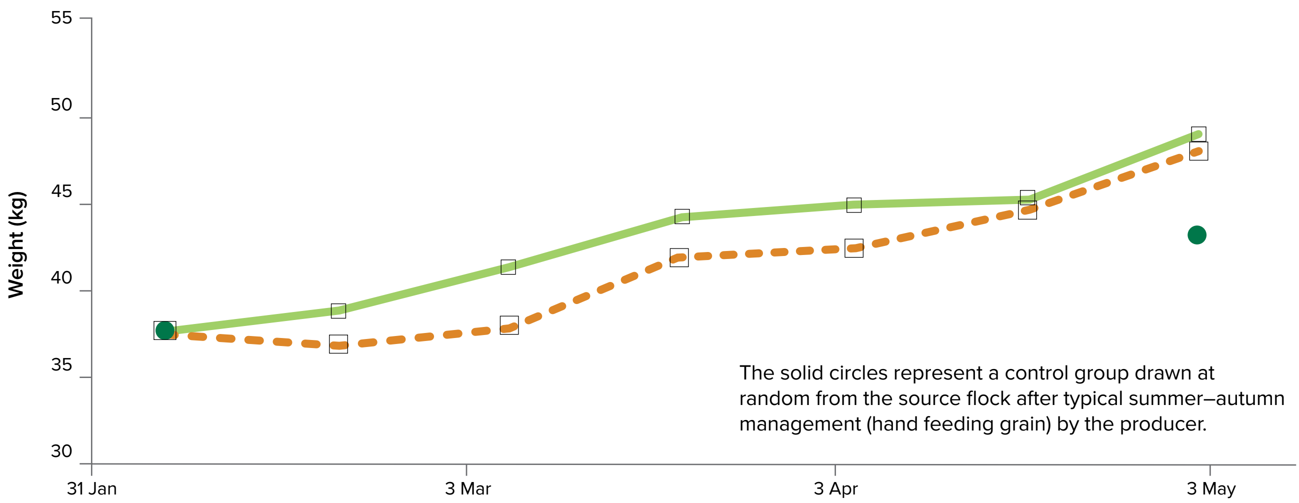


Figure 32. Live weights for rotational (dashed lines) and continuous (solid lines) tedera grazing at Kojonup in 2017.

Tedera samples taken from grazing experiments were separated into leaf and edible stem. As expected, leaf material was higher quality compared to edible stem, although the edible stem portion remains easily digestible and nutritious.

Table 5 summarises the chemical and nutritional analyses of tedera material sampled over the spring, summer and autumn period reported from plants grown at Mount Barker, WA.

The results in Table 5 indicate sheep may need some supplementation (in the form of salt) to compensate for the low levels of sodium and chloride in tedera. Sulphur supplementation could also be considered for wool-producing breeds of sheep.

Table 4. The concentration of CP, DMD and ME of the seven accessions of tedera in samples of edible leaf and stem.

Attribute	Season of grazing			
	Winter	Spring	Summer	Autumn
CP (%)	13.8	15.3	12.6	17.9
DMD (%)	72.8	69.6	74.1	70.2
ME (MJ/kg DM)	10.9	10.4	11.1	10.5

MJ = megajoules

Table 5. Nutritional analyses of tedera from September 2010 to April 2011 at Mount Barker, WA.

Attribute	Sep-10	Nov-10	Feb-11	Apr-11	Average
CP (%)	15	17.2	21.7	14.1	**17**
NDF (%)	37	40.9	34.1	34.5	**36.6**
ADF (%)	21	25.3	21.5	22.1	**22.4**
ASH (%)	8	7.5	8.6	8.7	**8.3**
OM (%)	92	92.5	91.4	91.3	**91.7**
DMD (%)	85	74.6	77.3	75.8	**78.1**
DOMD (%)	78	70.1	72.3	71.1	**73**
ME (MJ/Kg DM)	13	11.2	11.7	11.4	**11.8**
WSC (%)	11.6	5.9	4.3	6	**6.9**
Phosphorus (P) (g/kg)	1.8	1.5	1.7	0.9	**1.5**
Potassium (K) (g/kg)	12	8.8	14.2	8.3	**10.7**
Sulphur (S) (g/kg)	1.5	1.4	1.8	1.1	**1.4**
Sodium (Na) (g/kg)	0.8	0.6	0.3	0.4	**0.5**
Calcium (Ca) (g/kg)	20.8	18.5	18.2	21.2	**19.6**
Magnesium (Mg) (g/kg)	4	3.9	5	7.9	**5.1**
Chloride (Cl) (g/kg)	2.1	1.6	1.5	1.2	**1.6**
Copper (Cu) (g/kg)	9	9	8	5	**8**
Zinc (Zn) (g/kg)	28	32	29	19	**27**
Manganese (Mn) (g/kg)	123	77	66	55	**80**
Iron (Fe) (g/kg)	156	151	259	673	**310**
Boron (B) (g/kg)	35	29	38	38	**35**

CP (crude protein), NDF (neutral detergent fibre), ADF (acid detergent fibre), ASH (ash), OM (organic matter), DMD (dry matter digestibility), DOMD (digestibility of organic matter in dry matter), ME (metabolisable energy), MJ (megajoules), DM (dry matter) and WSC (water-soluble carbohydrates).

Is it palatable?

For successful animal production tedera must be sufficiently palatable to enable sheep to achieve an adequate intake to meet their nutritional requirements.

Several experiments were undertaken to evaluate the preference of sheep to tedera. Trials evaluated two different accessions of tedera in the presence of lucerne. There was no significant difference between palatability of the two tedera accessions. Naïve sheep had a clear preference for lucerne on the first day of exposure to tedera, but by the sixth day, sheep were grazing more tedera (two accessions combined) than lucerne.

Research evaluated the voluntary feed intake of tedera by sheep with prior exposure to grazing tedera relative to naïve sheep and the intakes were not significantly different. Also, the relative preference by sheep for wilted and fresh tedera accession was studied and found there was also no significant difference.

Sheep grazing tedera should not require supplements or hay and no induction or introduction feeding is required.

TOP TIP

Is it safe to eat?

There are no reports in scientific literature or by producers of tedera causing photosensitisation or any other health problems in grazing animals. No toxicity for grazing animals has been reported for tedera. After a few days of initial familiarisation, tedera is grazed readily.

Bloat can be a problem for ruminants grazing highly digestible pastures with high protein content and no condensed tannins, commonly the case with many legume-based forages. Tedera has a lower protein content than lucerne, a species which can cause bloat. Tedera also produces polyphenolics (2%) and condensed tannins (0.5%) and there has been no case of bloating in Australian or international tedera research or by traditional users in the native environments.

Research is still underway into its impact on cattle. Researchers cannot give any advice on the bloat impact on cattle at this stage.

In the paddock

An MLA Producer Demonstration Site (PDS) compared Merino lambs grazing on tedera with lambs grazing serradella/ryegrass, both for 57 days. The tedera pasture produced 325kg/ha of live weight during the trial compared to the control's 70kg/ha. This equates to a carrying capacity of tedera of 13.5 DSE/ha (in 2021).

The PDS site, located on 12ha at Dandaragan, was grazed twice in 2022. The first grazing was with 166 lambing twin-bearing Merino ewes from mid June to mid August. Lamb marking percentage (170 versus 164%) was similar to the control pasture (serradella and self-sown barley) but lambs marked/ha was significantly greater (22.7 versus 4.5) for the tedera due a significantly higher ewe stocking rate.

The second grazing was with 300 recently weaned Merino wether lambs from mid October to late November. The tedera grazed lambs had a slightly lower average daily live weight gain than the control (annual pasture) lambs (114g/hd/day versus 125g/hd/day), but because of the significantly higher stocking rate (25 lambs/ha versus 13 lambs/ha) the tedera pasture produced significantly more lamb live weight (105kg/ha versus 61kg/ha) over the same 37 day period.

Section 5. Achieving long-term tedera productivity

Weed control

- **Weed control is imperative for successful establishment and long-term productivity. Tedera seedlings do not compete well with winter weeds.**
- **Research has identified several broadleaf and grass-selective herbicides for pre and post-emergent use with tedera.**

Tedera seedlings do not compete well with winter weeds.

Research from eight herbicide experiments identified several broadleaf and grass-selective herbicides for pre and post-emergent application with tedera. Results were published in the scientific peer-reviewed journal *Agronomy* in 2022 (doi.org/10.3390/agronomy12051198).

Currently available herbicides to use on tedera are (see further information in Table 6):

- propyzamide (mainly to control grasses) as a pre and/or post-emergent
- flumetsulam (to control broadleaf weeds) as pre and/or post-emergent
- diquat and paraquat as desiccants on established tedera during winter for a clean-up of all weeds or at harvesting time
- diclofop-methyl, fluazifop-p butyl-ester and propaquizafop as post-emergent grass selectives.

Negotiations for further permits and minor use permits with the APVMA (Australian Pesticides and Veterinary Medicines Authority) are ongoing. Please contact your advisor for further information on herbicide use.

Table 6. Herbicides registered for use in legume pastures or pasture including tedera for weed control and/or dessication.

Product name (most common available) (registrant)	Active constituent (concentration)	Pasture description (weeds controlled)	Comments
Agrifop 375 (Sipcam)	Diclofop-methyl (375g/L)	Pasture (annual ryegrass, wild oats)	A post-emergent grass-selective Group A herbicide with known resistance in annual ryegrass and wild oats.
Reglone® (Syngenta)	Diquat (200g/L)	Pasture (capeweed, erodium, barley grass, brome grass, silver grass, vernal grass)	A post-emergent broad-spectrum Group L herbicide registered for pasture renovation and establishment. Will burn all green plant tissue.
Fusilade® Forte 128 EC (Syngenta)	Fluazifop-p butyl-ester (128g/L)	Pasture (annual phalaris, annual ryegrass, barley grass, brome grass, volunteer cereals, wild oats)	A post-emergent grass-selective Group A herbicide with known resistance in annual ryegrass and wild oats. Only Fusilade® Forte 128 EC includes 'pastures'.
Broadstrike® (Corteva)	Flumetsulam (800g/kg)	Pasture (various broadleaf weeds)	An early post-emergent broad-spectrum Group B herbicide.
Gramoxone® 360 Pro (Syngenta)	Paraquat (360g/L)	Pasture (annual grasses and broadleaf weeds)	A post-emergent broad-spectrum Group L herbicide registered for pasture establishment, pasture cleaning, spray-topping and the prevention of annual ryegrass toxicity. Will burn all green plant tissue.
Shogun® (ADAMA)	Propaquizafop (100g/L)	Legume pasture (annual ryegrass, barley grass, brome grass, volunteer cereals, wild oats)	A post-emergent grass-selective Group A herbicide with known resistance in annual ryegrass and wild oats.
Edge 900 WG (Imtrade)	Propyzamide (900g/kg)	Legume pasture (various annual grasses and broadleaf weeds)	A post-emergent broad-spectrum Group D herbicide which can be applied to seedling and established crops.

Note: Several labels for each active have been checked to ensure the 'pasture' terminology is consistent. But all product labels for each active constituent were checked. For any product selected, check the label carefully to ensure that tedera is covered by the legume pastures/pasture legumes wording.

Section 6. Pests and disease management

Pest and disease control

- Tedera is relatively tolerant to aphids and nematodes.
- Native budworm must be managed in seed crops.
- Red-legged earth mite (RLEM) do not seem to cause an economic impact.
- *Phoma herbarum* (a fungal disease), phytoplasma and Alfalfa mosaic virus have been observed in tedera but their economic impact has not been measured.

Pest challenges

Native budworm *(Helicoverpa punctigera)* is a major pest of pulse and canola crops in WA and trials found tedera's immature seeds were susceptible to native budworm and seed production could be impacted without control. Most tedera production will be established for direct grazing purposes and native budworm control is not necessary. Native budworm can breed in arid inland areas after winter rains before migrating to the agricultural areas in late winter and spring with the aid of high-altitude air currents.

Native budworm should be controlled in tedera seed crops. Two or three applications of alpha-cypermethrin at 20g of active ingredient/ha every three weeks, starting in early flowering, is effective to avoid damage to tedera seeds. In seed crops it is recommended to monitor the moth numbers with pheromone traps and start the applications if moths are present. When you see the damage in the seed, it is already too late for an effective control.

The last two growth stages (fifth and sixth instar) will start to defoliate plants, but tedera outgrows foliar damage caused by native budworm.

Figure 33. Native budworm. Photo courtesy Christiaan Valentine.

RLEM/aphids susceptibility was not quantified by any experiments up to date. It was observed that even though tedera was attacked by RLEM, it does not seem to be killed or seriously affected, unlike many other annual legumes such as sub-clover. However, it is beneficial to control RLEM when sowing tedera to avoid damage to cotyledons, which would reduce vigour and growth.

Tedera is tolerant to aphids. No specific experiments have been conducted but it has been observed that, even when surrounded by companion plants covered in aphids, tedera has only a few aphids and no damage symptoms.

Pratylenchus neglectus (the most common root lesion nematode (RLN)) is a typical migratory endoparasite which causes yield losses in the main broadacre crops grown in WA. No economically viable chemical control currently exists in broadacre cropping, so management of RLN in infested paddocks relies on crop rotation and variety choices which either reduce or maintain RLN levels below that which could cause yield loss. Several pasture and rotational crops exist which will effectively reduce *P. neglectus* in infested paddocks, but more choices are needed to help growers manage RLN economically. In early experiments Lanza® tedera was resistant to RLN *P. neglectus,* offering similar resistance as lupins and serradella, but further screenings are needed for ratings to be determined. This resistance means Lanza® tedera could offer break crop opportunities for growers managing *P. neglectus*.

Disease challenges

Phoma herbarum is a fungal plant pathogen which causes pale brown lesions on tedera leaves of 1.5–4mm in diameter, which develop a distinct, dark brown margin. Occasional lesions also show a distinct chlorotic halo extending 1–1.5mm outside the boundary of the lesion (Figure 34). The disease was originally identified in plants grown under irrigation in genetic evaluation plots of tedera. Symptoms are evident within 10 days of inoculation. *Phoma herbarum* has also been noted as occurring on lucerne and soybean in WA. It is not known if *P. herbarum* has an economic impact on tedera production in the wheatbelt.

Figure 34. *Phoma herbarum* symptoms in tedera.
Photo courtesy Dr Daniel Real.

Phytoplasma are phloem-inhabiting bacterial organisms transported via leaf-sucking insects, such as leafhopper, and causing considerable damage in more than 1,000 plant species around the world. Phytoplasma causing 'witches' broom'-type symptoms including stunted growth with small leaves, shortened internodes and bushy growth, was found in tedera seed multiplication nurseries at Medina and was named 'Bituminaria witches'-broom phytoplasma' (BiWB).

Figure 35. Tedera with parts of the plant showing phytoplasma (BiWB) symptoms and part of the plant growing normally.
Photo courtesy Dr Daniel Real.

Phytoplasma causing damage to tedera are native to Australia. There is no evidence that phytoplasma disease is seed-borne. Therefore, tedera stands are free of phytoplasma in the early stages, with the disease appearing in older the plants if native phytoplasma and leafhoppers are in the same area. Usually, the most damage is seen in autumn at the end of the dry season when plants have been growing slowly for a long period and the multiplication of the phytoplasma affects a larger proportion of the plants. Once the growing conditions improve, the unaffected parts of the plant can quickly outgrow the phytoplasma multiplying within the affected parts.

Leafhoppers are a vector for plant viruses and phytoplasma. Leafhoppers can be controlled with insecticides and growers should look for phytoplasma and leafhoppers in neighbouring areas and apply insecticides accordingly. Phytoplasma is not transmitted by seed.

Alfalfa mosaic virus (AMV) was confirmed to infect tedera by trials. AMV caused calico (bright yellow mosaic) leaf symptoms on tedera plants growing in genetic evaluation plots at Newdegate in 2007 and Buntine in 2010. Lucerne buffer rows were likely sources for spread by aphids to healthy tedera plants. For advice on managing AMV in tedera crops, growers should follow the advice available for other perennial pasture plants. While AMV is not a major issue, growers can control the aphids which spread it (with insecticide) but not the virus itself.

Section 7. Seed harvesting

Seed production

- Tedera flowers over several weeks and seed ripens unevenly.
- All livestock should be removed by the end of July to allow growth in late winter ahead of flowering in early October.
- Optimum harvest time is around six weeks after the peak of flowering.
- Harvest must be timed right, as ripe seed can drop.
- Tedera plants are green and leafy when seed ripens so swathing or chemical desiccation is required prior to harvesting with a header.
- Header harvesting can yield up to 300kg/ha clean seed.
- Pollinators are important for high seed set.

Time of flowering and seed set

Tedera is an indeterminate flowering species with an average peak of flowering in October. The flowering period is spread over several weeks and the peak of mature seed production occurs approximately six weeks after the peak of flowering. Therefore, at a single point in time in late spring, tedera can have a mixture of seeds which are ready for harvest or immature, along with open flowers.

Nineteen accessions of tedera were trialled at Medina, WA, in 2009 for seed production characterisation. It found all accessions had different flowering times. Mature seeds were ready for harvesting 42 days after pollination, most seeds had dropped by 65 days and all seeds were dropped by day 83.

The window of opportunity to harvest is very narrow, with just a three-week window from maximum seed yield (day 42) to not worth harvesting (day 65).

Defoliate before flowering

To reduce leaf biomass at flowering and provide a more favourable leaf-to-root ratio and water balance in late spring, seed crops can either be grazed or desiccated with a herbicide in early to mid-winter.

Use of a herbicide will have the dual purpose of controlling annual weeds and reducing leaf area. Another advantage is both management options will delay flowering for two to three weeks in comparison with un-defoliated stands, pushing full flowering later into spring when average temperatures are more often above 15°C and reducing the risk of frost at flowering time.

Figure 36. Good pollination helps tedera seed production. Photo courtesy Peter Maloney.

The importance of pollination

While tedera is a self-pollinated species capable of producing its own seed without pollinators, encouraging insect pollinators lifts seed production. WA trials comparing areas covered with insect-proof mesh to no restriction on honeybees found bees visiting the flowers led to 1,083kg/ha of seed production compared to 560kg/ha in covered areas.

As flowering coincides with the timing for native budworm control it is suggested producers use honeybee-friendly insecticides or time sprays to avoid impacting foraging honeybees (after sunset or before sunrise).

How do I harvest tedera seed?

Several methodologies were researched to optimise seed harvest in tedera, including multiple harvest and single harvest technologies. It concluded a single harvest was the easiest and most practical technology to harvest tedera in large-scale operations. A conventional grain harvester without any special modifications was sufficient and practical, with only adjustments to the settings as required.

Being a perennial plant, tedera remains green once seed is mature. Therefore, it needs to be desiccated with a chemical spray or cut and swathed and allowed to dry for a few days to be harvested when fully dry.

Paraquat and diquat are effective desiccants in adult tedera plants, which can recover well after treatment (see Section 5).

Desiccation has been the preferred method of harvesting tedera to date, while cutting and swathing has not yet been tested at commercial scale.

Figure 37. Lanza® tedera harvesting from desiccated seed crop at Dandaragan on 19 December 2016. Photo courtesy David Clegg.

Where do I go for more information?

For information and videos: www.agric.wa.gov.au/pasture-species/lanza%C2%AE-tedera

For information on native budworm: www.agric.wa.gov.au/grains/management-and-economic-thresholds-native-budworm

For information on AMV: agriculture.vic.gov.au/biosecurity/plant-diseases/grain-pulses-and-cereal-diseases/alfalfa-mosaic-virus

Use the TIMERITE tool for establishing the optimum control period for RLEM: www.wool.com/land/timerite

Use the CESAR RLEM hatching tool to establish timing of hatching: cesaraustralia.shinyapps.io/RLEM-hatch/

Dr Daniel Real, daniel.real@dpird.wa.gov.au

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MEAT & LIVESTOCK AUSTRALIA

Meat & Livestock Australia Limited

Level 1, 40 Mount Street, North Sydney NSW 2060
Phone: 02 9463 9333 I Email: info@mla.com.au

mla.com.au