Growing Tagasaste in New Zealand

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Contents

Executive Summary

This handbook has been produced for farmers and others who grow, or want to grow and learn about tagasaste. It draws on the published literature on tagasaste in New Zealand and overseas, plus the practical experience of those who have worked with tagasaste. Key results from the Sustainable Farming Fund project 'One Winter – Two Springs' (Project No. 405641), on tagasaste establishment and management in hill country pastures, are included. The handbook covers the growth requirements of tagasaste, its uses, forage production and quality, practical guidelines on its establishment and management, economic benefits, practical tips from experienced growers and frequently asked questions. Suggestions are provided for further reading, including the published literature on which this handbook is based.

What is tagasaste?

Tagasaste is a small evergreen tree. It is fast growing, drought tolerant and fixes nitrogen in the soil. Tagasaste originated from La Palma in the Canary Islands, off the coast of north-west Africa, and was introduced to New Zealand and Australia in the late 19th century, primarily for use as forage. Tagasaste is best adapted to drought-prone flat land or hill country with free-draining soils. It grows well in low rainfall areas but can tolerate higher rainfall where soils are well drained, such as on pumice. It will not tolerate waterlogged soils and will only survive for a few years on periodically wet soils where it is susceptible to root rots. Seedlings can be killed by frosts, but mature trees tolerate frosts as low as -9°C. It can grow in coastal conditions and on windy sites.

Uses

Tagasaste is a multi-purpose species. It provides feed and shelter for livestock, is used for soil conservation, is used as a nurse crop for native plantings and provides bee forage. Other uses include amenity horticulture, carbon sequestration, winter feed for native birds and providing quality firewood.

Forage production

In New Zealand, stands of tagasaste can produce up to 27 tonnes of edible dry matter (EDM)/ha/yr, but typically produce less than 10 t/ha/yr. Leaf material has a high crude protein content (18-30%) and moderate to high dry matter digestibility (>70%). Leaves are rich in minerals required in trace quantities and provide a valuable supplement as a browsed feed in hill country pastures.

Establishment

Tagasaste has a hard seed coat which requires scarification to enable germination. This can be done by placing seeds overnight in hot water. Sowing treated seeds directly into root trainers or similar produces seedlings suitable for planting within 8-10 months.

Tagasaste competes well with pasture species and weeds after planting but growth is faster if they are controlled. Although mature tagasaste trees can be lightly grazed, seedlings must be protected from grazing during establishment.

Wide-spaced tagasaste grown on pasture can be established using two methods:

1. Seedlings may be planted in a well-fenced paddock with stock exclusion for up to two years after planting
2. Trees can be protected individually, and grazing can continue.

Trees can be as close as 1.5 m within shelter rows or up to 8 m × 8 m if used for soil conservation on hill country.

Management

Stands of tagasaste can be managed by cutting, direct grazing or a combination of both. Tagasaste plants can be lightly grazed by young sheep about two years after planting. Once trees are well established, they can be carefully grazed by cattle provided no more than 80% of the foliage is removed. Trees can be trimmed after grazing to encourage branching and maximise EDM production.

Economic benefits

Planting tagasaste can result in substantial financial benefits. Based on a case study farm near Wairoa, it is estimated that the direct financial benefits of tagasaste planted on a hill country paddock at 8 m x 8 m spacing (156 stems/ha) include its feed value ($114/ha/yr) and N-fixing contribution ($62/ha/yr), totalling $176/ha/yr (based on the cost of goods and services as of November 2021). It was also estimated that the contribution of tagasaste to the prevention of soil erosion may have a value of over $250/ha/yr. Beekeepers may also benefit from the contribution of early flowering of tagasaste to honey production by up to $300/ha/yr. The total estimated benefit is $726/ha/yr.

Key findings from the Sustainable Farming Fund project 'One Winter – Two Springs'

- A single tagasaste tree, trimmed every 12 weeks over 12 months, produced ≈2.7 kg EDM/tree/yr, with the lowest production occurring in autumn.
- The content of metabolisable energy (9.4-10.7 MJ/kg DM) in tagasaste was within the range of values that occur for perennial ryegrass during summer and autumn but was lower than values typical of white clover and red clover.
- The crude protein content of tagasaste varied from 17% to 23% and neutral detergent fibre from 32% to 43%.
- Mean concentrations of all minerals in tagasaste in each season, apart from phosphorus, exceeded those recommended for an adequate intake for sheep/cattle.
- Branch diameter or branch length were not found to be good predictors of EDM production. A trial was conducted on a sheep and beef hill country farm north of Wairoa on a steep (30°), north-facing slope to quantify the growth of pasture species when grown beneath tagasaste trees and in adjacent open pasture.
    - Total annual DM production per plant was reduced in heavy shade by about 70% when compared to open pasture.
    - Survival was much higher for the grasses than the legumes with few legumes surviving beyond the second year of the study.
    - Cocksfoot performed the best of the grass species with the highest survival, DM and ground cover, and a high metabolisable energy content. It suffered little damage from insect pests and diseases.
    - Lotus performed the best of the legumes. It had the highest survival, high DM and ground cover, provided high metabolisable energy, and suffered low levels of damage from insect pests and diseases.
- Placing seeds into water that had just been boiled and left to cool overnight is a simple and effective method of scarifying the seed coat and germinating tagasaste seed. Alternatively, tagasaste seedlings can be sourced from commercial plant nurseries.
- Establishment of tagasaste in resident pastures in summer-wet hill country is unlikely to be successful from sowing seed.
- Defoliating tagasaste seedlings severely (80% of stem height removed) compromised regrowth and had no benefits for increasing the branch number when compared to removal of the top 20% or 40%. Seedlings averaged 45 cm in height when the defoliation treatments were imposed.

This handbook brings together most of the Australasian knowledge on the establishment and management of tagasaste and estimates its value when used as a supplement to pasture. The authors hope that this collection of knowledge will save growers numerous hours of research and that the results from the Sustainable Farming Fund project are of practical interest.

Introduction

Growing tagasaste has a long history in New Zealand and there have been numerous studies in Australasia to assess its value in agriculture. The information can be difficult to gather and interpret because the studies have been done in many locations with varied results.

This handbook brings together multiple sources of information for easy comparison and new science on tagasaste, including results from the Sustainable Farming Fund (SFF) project ('One Winter – Two Springs' Project No. 405641). The SFF project focused on the establishment and management of tagasaste in East Coast North Island hill country pastures and, particularly, on identifying suitable understorey pasture species which perform well when grown with tagasaste. This research was carried out on Nick Broad's property, 'Waituku', near Wairoa, over three years.

This handbook provides practical guidelines on its uses, how to establish tagasaste (including establishment costs), planting and management options, nutritive value, EDM production and financial benefits. This information is drawn from the personal experience of farmers, rural professionals, researchers and others, as well as from published literature. This handbook aims to be a 'go to' manual for the pastoral farmer, particularly on hill country.

The project has been funded by:

- The Ministry for Primary Industries
- Beef + Lamb New Zealand Ltd
- Hawke's Bay Regional Council
- Ballance Agri-Nutrients Ltd.

"Today tagasaste has been the plant to flourish, self-recreating, building soil and offering grazing. The flower produces bee-enhancing food in excess. This has greatly increased the survival of our queen bumble bees and pollinators of our lucerne seed in February".

Doug Avery, proving the value of tagasaste on the driest of farmed hill country, 'Bonavaree' in Marlborough.

"Our regenerative style of farming lends itself very well to pasture-tree combinations. Tagasaste is one of the nitrogen-fixing trees which we use in combination with others to provide a variety of benefits to the farm. It is fast growing and provides shelter for livestock as well as being there as a feed source if needed."

Greg Hart, Project Chairman, farms 'Mangarara' in Central Hawke's Bay.

"I'm looking for shade, shelter and erosion control on my hills. Tagasaste is a tree which can do this while maintaining our carrying capacity and it's great to have the native birds around in winter."

Nick Broad, farmer in steep Wairoa hill country.

What is tagasaste?

Description

Tagasaste (*Cytisus proliferus* L. f. var. *palmensis* Christ) is a small, fast growing, drought tolerant, nitrogen-fixing evergreen tree.

The canopy is typically spreading, open and oval/elliptical. It grows to a height of 7 m, with drooping branches with grey-green leaves.

The leaves are trifoliate with short hairs underneath, with lanceolate leaflets (like a narrow oval tapering to a point), 20-35 mm long × 4-10 mm wide.

It has a profusion of creamy-white, pea-shaped flowers from late winter to mid spring and produces flattened brown/black pods 3.0–5.0 cm long × 1.0 cm wide (Figure 1). Each pod contains 6–10 flattened, black, glossy seeds. Tagasaste seeds are larger and heavier than seeds of standard pasture species with a weight of 25–35 g per thousand seeds. The mature pods explode in summer, spreading the seed up to several metres from the parent plant.

There is much genetic variation within and between tagasaste populations for morphological (e.g., growth habit) and other (e.g., plant survival, growth rate, production) attributes, and some selections have been developed. For example, a weeping, low-growing selection has been developed in Western Australia named 'Cleavers Easy Graze'. In the lower North Island of New Zealand, a programme involving 16 elite lines from throughout the country produced an unnamed final selection that had high survival (>80% as spaced plants), improved production, growth habit and tolerance to frost and disease.

1a: Trifoliate leaves.

1b: Pods in late spring (November) changing from green to black.

1c: A typical mature tree on hill country.

Figure 1: Images of tagasaste.

Origin and distribution in New Zealand

Tagasaste originated from La Palma in the Canary Islands, off the coast of north-west Africa and has spread to other countries with a Mediterranean climate. It was introduced to New Zealand and Australia in the late 19th century, where it is primarily used as forage [1-8]. While commonly known as tagasaste, other names include tree lucerne, white-flowered tree lucerne and false tree lucerne.

Tagasaste has been grown successfully in numerous parts of New Zealand, particularly on the east coast in Bay of Plenty, Wairarapa, Marlborough and North Canterbury (Figure 2).

Growth requirements

Tagasaste can grow up to 400 m above sea level in the North Island and up to 200 m above sea level in the South Island.

Tagasaste grows best on drought-prone flat land and north-facing hill country. Overseas, tagasaste has survived in semi-arid environments with an annual rainfall of 200 mm. It can grow well in higher rainfall areas (e.g., >1200 mm/yr) provided soils are free-draining. Tagasaste is susceptible to root rots caused by fungi (e.g., *Phytophthora* and *Fusarium*) when soils remain damp or waterlogged.

Tagasaste seedlings are frost-tender and can be killed by frosts, but mature trees tolerate frosts as low as -9°C.

Established plants appear to be unaffected by temperatures of 30-35°C except for occasional leaf wilting on very hot days. Under very dry conditions, growth can be stunted, and leaves shrivel and die. Tagasaste grows in coastal areas and other sites exposed to moderate to strong winds.

The optimum soil pH range for tagasaste is unclear but it can grow well in soils with pH varying from 5.0 to 7.0. Like many plants, growth is reduced in alkaline and saline soils. Tagasaste may respond to the addition of superphosphate or other fertiliser types, but results have been inconsistent.

Tagasaste is susceptible to stem boring insects such as Pūriri moth (*Aenetus virescens*) which is present in the North Island, and lemon tree borer (*Oemona hirta*) which is present in both the North and South Islands [4]. Both pests mainly attack older trees and can reduce plant longevity.

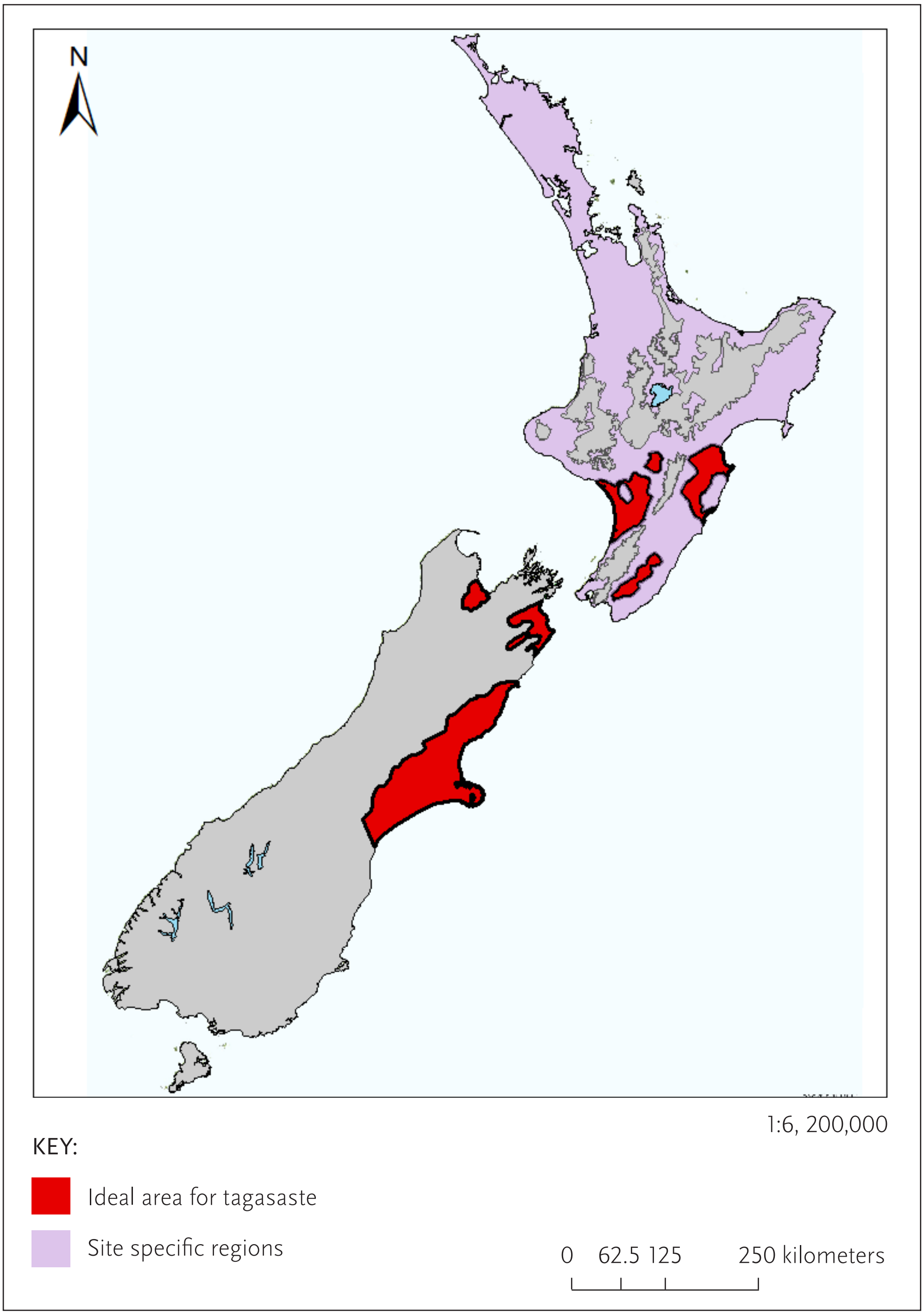


Figure 2: Zones suitable for tagasaste establishment and growth in New Zealand.

Red areas: annual rainfall is below 1000 mm and tagasaste grows well but is susceptible to frost damage.

Mauve areas: higher rainfall, tagasaste growth will be successful where soil types are well drained and heavy frosts are uncommon.

Grey areas: The remainder of the North Island and parts of the South Island have microsites where tagasaste can be grown although much of this grey area either has wet/heavy soils or frost-prone conditions.

Uses

Tagasaste has multiple uses with benefits for agriculture, soil conservation and native species.

Agriculture

Tagasaste provides a range of production benefits, including the provision of fodder as discussed on page 12.

Tagasaste can provide livestock with both shade and shelter, both of which have multiple benefits [9, 10]. For example, providing cattle with shade from stands of willows increased the amount of time each day that cattle spent grazing [11]. In a twin calf study involving sheep and cattle, the twin provided with shelter grew faster than the twin without shelter. Shelter also reduced lamb deaths in the first few days after lambing [12].

Tagasaste provides nectar and pollen for pollinators at a time when other food sources are scarce [13], such as for bumble bee (*Bombus terrestris*) queens when they emerge from hibernation after winter (Figure 3). This improves the egg-laying ability of the queen, strengthening bee colonies. Tagasaste also provides food for the bumble bee species *Bombus ruderatus* which also pollinates red clover. Honey bees also benefit from tagasaste in early spring, although their access to the pollen relies on the presence of the larger bumble bee to 'trip' the flowers open for them [7].

Erosion control

Tagasaste has an extensive lateral and vertical root distribution and is more likely than pasture species to reduce soil-slip erosion. Dense stands of tagasaste may be more effective than isolated trees or sparse plantings in reducing erosion risk, as interlocking tree roots help hold the soil in place. The trees also take up water and dry out the soil, more so than pasture, which can make the soil less prone to slipping. The canopy can also intercept rainfall and reduce soil erosion. On drier sites, tagasaste shelter belts can reduce wind erosion, depending on plant spacing and orientation of rows in relation to prevailing winds [14].

Sustaining native flora and fauna

Tagasaste seedlings can grow between 1 and 2 m per year and this rapid growth can provide shade and shelter for slower establishing native vegetation [4, 15]. These sheltering effects diminish as tagasaste matures and dies after 8-10 years on wetter soils or 15+ years on well-drained soils.

From June to September, tagasaste shoots provide a valuable feed for kererū (New Zealand wood pigeon, *Hemiphaga novaeseelandiae*) when other food sources are scarce.

Figure 3: Bumble bee foraging on tagasaste for pollen and nectar.

Other uses

Tagasaste in full flower is a stunning component of the vegetation mosaic in roadside, urban and rural landscapes (Figure 4). Other uses include carbon sequestration [16] and production of quality firewood. All of these are examples of ecosystem services – the benefits people obtain from nature.

Potential issues

Tagasaste may be weedy in some situations because of its prolific seed production, high hard seed content which enables buried seed to remain viable for many years, and rapid growth of young trees. This may allow it to rapidly colonise dry sites that have been disturbed or which have low ground cover, such as gravelly riverbeds. Given that tagasaste seedlings are killed by heavy frosts and they require well-drained soils for establishment, areas where it can naturalise and form dense stands are limited.

Figure 4: Flowering tagasaste on Bonavaree Farm.

Growing tagasaste: Bonavaree Farm

Doug Avery – Bonavaree Farm, Grassmere, Marlborough

Doug is well known in the rural sector for his innovative approach to farming. He partnered with researchers from Lincoln University to develop the lower slopes of his dryland hill country property using lucerne as a main feed crop for livestock, and for shade and shelter. Doug reviewed his land use at Bonavaree and decided that pasture alone was not sufficient to get him through the long, hot summers. Doug planted the forage shrubs, tagasaste and salt bush (*Atriplex halimus*) on his steepest gravelly, erosion-prone hillsides. Tagasaste has survived and re-seeded on these sites and has produced edible feed for cattle.

Bulls are let into the tagasaste plantings in times of feed shortage. They reduce the rank grass and control tagasaste growth. The cattle break some of the branches of tagasaste plants when grazing which results in plants producing multiple branches, especially when cattle have grazed younger plants. Doug notes that when compared to single-stemmed shrubs, multi-stemmed shrubs have more ground cover and produce more feed for subsequent grazings.

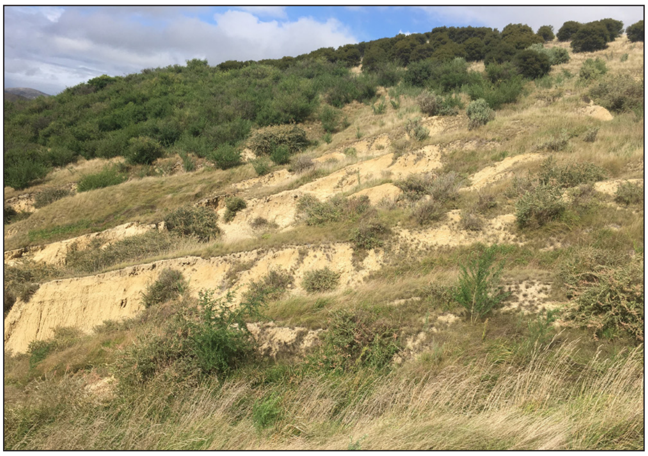
The accompanying photos (Figure 5) show how long rest periods (1+ year) enable buried seed to germinate and produce new seedlings without farmer input. Long periods without stock pressure are possible in this environment where weed problems are minimal. This contrasts with North Island East Coast areas such as Wairoa and Gisborne where weeds can become a problem. Ongoing seedling establishment provides a constant source of forage, replacements for older trees, and revegetation of sites within blocks which previously had no cover.

The second important role of tagasaste at Bonavaree is to provide a late winter feed source and habitat for bumble bees which are an important pollinator of the farm's lucerne crop.

Doug is now also planting tagasaste on steep hill faces for temperature control. "The hard faces of Grassmere reach over 50 °C in summer and woody shrubs create a cooling effect" says Doug. "We are now looking at increasing the number of plantings in our poorer country – if we have global warming we must respond with a cooling process of the soil".

5a: Tagasaste seedlings establishing on drought-prone hillsides.

5b: Hill slopes where tagasaste is planted.



5c: Hill slopes where tagasaste is planted. Note the salt bush in the foreground.

Figure 5: Tagasaste on Bonavaree Farm.

Forage production and quality

Production

Total production of tagasaste in New Zealand is estimated to be 1.7-17.9 t DM/ha/yr depending on plant age, location and management (Table 1).

In Canterbury, tagasaste trees produced 2.02 kg EDM/tree/yr [2]. Therefore, a stocking rate of 5445 tagasaste trees/ha would be needed to produce 11 t DM/ha/yr.

In Wairoa, tagasaste produced 2.7 kg EDM/tree/yr (Appendix 1). Attempts were made to identify branch characteristics (e.g., branch length, diameter) that could help farmers predict the amount of EDM produced from each branch but this was not successful (Appendix 2).

Tagasaste seedlings which establish beneath the dense tagasaste canopy can also provide fodder but the amount produced has not been quantified.

Total and EDM production of tagasaste are presented in Table 1. Studies differ in site characteristics, plant age and how plants were grown and managed (cutting, browsing or both).

Tagasaste is often established in existing pastures without altering the understorey pasture species. Densely planted stands can shade the pasture, reducing pasture growth and quality (Appendix 5).

Pasture species can be introduced into a pasture-tagasaste system so the pasture remains productive, despite higher levels of shade (Appendix 5). Understorey pasture grasses may also benefit from nitrogen fixed by tagasaste.

Table 1: Total and edible dry matter (EDM) production of tagasaste (leaf + stem <5 mm diameter).

Site	Age of Plants (Years)	Plant density (Stems/ha)	Total annual DM production (t DM/ha/yr)	Total annual EDM production (t EDM/ha/yr)	EDM production percentage (%)	EDM per plant (kg EDM/plant)	Reference
Range in NZ and Australia	1-4	1670-10000	1.7-17.9	0.5-10.8	12-73	0.1-5.5	[2, 17-24]
Lower North Island (flat)	2.5	1670	4.5-10.4	0.9-1.2	12-21	0.5-0.7	[17]
Manawatū (moist, flat)	≤2 [a]	2670	14	2.4-3.7	34	0.9-1.4	[18]
Manawatū (dry, flat)	≤2 [a]	2670	8	1.6-1.9	40	0.6-0.7	[18]
Palmerston North (flat)	1	5000	1.7-7.3 [b]	UTC[c]	38-71 [d]	0.1-1.7 [d]	[19]
	2	5000	1.8-6.7 [b]	UTC[c]	29-35 [d]	1.3-5.5 [d]	[19]
Canterbury (N/NW faces)	2 or 3	10000	15.7-17.9	9.4-10.8	60 [e]	0.9-1.1	[2, 20]
Canterbury (flat)	>1 [f]	3260	10.7	6.4	62-73	2.0	[20, 21]
Australia (NSW)	3	Mixed	3.1-5.7	1.1-1.9	33-35 [e]	0.25-0.35	[22]
Australia (WA)	3	5000	6.4	2.6	40 [e]	0.5	[23]
Australia (WA)	4	1000	7.0	3.0	43 [e]	0.3	[24]

*'a' 20 – 24 months; 'b' range of population means; 'c' unable to calculate from reference data; 'd' range for individual plants rather than population means; 'e' edible yield/total yield * 100; 'f' 16 months.*

Feed quality

Tagasaste leaves are highly palatable to sheep, cattle, goats (and animal pests!). Its leaf longevity (3-5 months from emergence to senescence) is much longer than for temperate grass and legume species. Green leaf provides moderate to high quality feed throughout summer and autumn (Appendix 3), although drought can result in leaf death and a loss of quality. The crude protein/N content of foliage slowly decreases as leaves age, and the nutritive value of the foliage is reduced by flowering [25].

Tagasaste has a high crude protein content of 18-30% and moderate to high DM digestibility which often exceeds 70%. Leaf material has a greater crude protein content than stems so the thickness and amount of stem in the feed sample will affect the digestibility and protein content. Based on several studies, dry matter digestibility of leaf material ranged from 71% to 78% whereas stem averaged 46% [18, 25-27].

Tagasaste contains phenolic compounds such as condensed tannins [28].

At high levels, condensed tannins can reduce palatability, animal intake, digestibility and absorption of protein [29]. Consumption of tannins can also reduce methane gas emissions from livestock [30]. Their concentration in tagasaste varies. In Australia, concentrations have ranged from 0.5 to 5.0% in the cooler winter-spring period to 10-12% in the hot, dry late summer-autumn [31, 32].

Minerals

The levels of most minerals in tagasaste foliage exceed those required for lactating ewes with a single lamb ([33, 34]; Appendix 4).

- Sodium content of leaves was low, and levels of phosphorus and sulfur were marginal to meet animal requirements in Canterbury.
- Sodium content in foliage in Manawatū was low in a moist environment (silt loam soil, high rainfall) but exceeded animal requirements in a dry environment (sandy soil, lower rainfall, Table 2). Salt blocks have been recommended to meet sodium requirements although it is likely that livestock grazing in pasture-tagasaste systems would obtain adequate sodium levels from the pasture.
- Levels of sulfur, copper and zinc were marginal in the dry environment. Tagasaste is regarded as a good source of minerals, particularly calcium and those minerals required in very low amounts.

Table 2: Mineral concentrations in edible foliage (leaf + stem <5 mm) of tagasaste in February in Manawatū [18]. Shaded values indicate marginal levels.

Site	Forage	Nitrogen	Phosphorus [1]	Potassium	Sulfur	Calcium	Magnesium	Sodium	Copper	Iron	Manganese	Zinc
Moist	Tagasaste	3.21	0.24	1.65	0.16	0.47	0.13	0.02	6	74	139	47
	Pasture	2.89	0.29	3.48	0.21	0.70	0.23	0.08	12	98	70	27
Dry	Tagasaste	2.60	0.19	0.98	0.12	0.43	0.15	0.08	3	78	77	21
	Pasture	1.38	0.22	1.76	0.13	0.57	0.24	0.12	8	65	90	22
Ideal [2]		1.70	0.18	0.40	0.13	0.17	0.10	0.05	4	30	25	24

'1' Units are % of dry matter except for copper, iron, manganese and zinc, which are parts per million (ppm); '2' Recommended for adequate diet for lactating ewe with one lamb [33, 34].

Growing tagasaste: Waituku Station

Nick Broad – Waituku Station, Wairoa, Hawke's Bay

Tagasaste has multiple benefits on Nick's hill country farm (Figure 6).

Direct benefits for the pasture and livestock include:

- N-fixation
- Provision of forage (dry matter and minerals)
- Shade and shelter for livestock.

6a: An 18-month-old tagasaste plant enclosed within a tree-guard on a steep slope.

6b: Sheep enjoying shelter, shade and understorey grazing in the tagasaste plantation.

Figure 6: Tagasaste on Waituku Station.

Indirect effects include:

- Attracting native birds
- Bee feed
- General landscape appeal.

Further benefits include carbon sequestration in the woody stems, roots and soil organic matter. Another key benefit of planting tagasaste on Nick's farm is for soil conservation. This is especially important for Nick as his land lies in a catchment with highly erodible soils which are in danger of being lost from the hillside and ending up in a lake.

Nick aims to grow tagasaste in such a way that it does not reduce his farm's productive capability. Other tree species are being considered for soil conservation, although tagasaste has added value as a browse shrub, providing incidental feed to livestock. When foliage is plentiful and within reach of sheep or cattle, tagasaste provides valuable supplementary feed.

A 1-ha steep, northerly facing block was planted with approximately 600 tagasaste trees at 4 m × 4 m spacings in 2003. This area has been used for the Sustainable Farming Fund project which focussed mainly on determining the survival and productivity of selected pasture species growing beneath the tagasaste (Appendix 5). Livestock were excluded from the paddock for 3 years while the trees established. This gave an opportunity for blackberry to establish and it took Nick several years to control it. From the time of planting, tree growth was spectacular, flowering was profuse and Nick noted a big improvement in ground cover and leaf litter build-up which could increase organic matter levels in the soil. During the flowering period between July and September, large numbers of tūī and kererū visit the site to feed.

The trees were thinned to approximately 8 m × 8 m to allow more light into the pasture. Some trees died. This was probably because of heavy soils with higher than optimum moisture content for tagasaste. Drier areas of Hawke's Bay, Marlborough and Canterbury do not have this problem.

In 2017, an adjacent block of similar size was planted at 8 m × 8 m but with individual tree-guards. This enabled livestock to graze the pasture while the trees established without killing the tagasaste. The objective was to keep the grass green and leafy with better quality and to reduce blackberry regrowth. This has been successful but protecting individual trees increased the establishment cost (page 19). Both methods (i.e., individually protected or without individual tree protection) require very careful livestock management during establishment.

Practical guidelines: Tagasaste establishment

Guidelines are provided below on how to collect, clean, store and germinate seed, followed by tips for establishing and managing tagasaste.

Seed collection

- Identify flowering trees in late winter and check developing seed pods regularly.
- Collect the seeds when the pods are brown/black – but before the pods burst open and the seed is lost. In the North Island, pods may be ready to harvest by mid-December.
- Focus on collecting seed from branches with many pods.
- Use gloves for harvesting as the pods and branches can be sharp.
- A tarpaulin may be placed beneath 'seed trees' to collect seeds that fall from the pods.

Seed cleaning and storage

- Find an area of concrete in a sheltered space in full sunlight.
- Spread the collected seedpods.
- Turn the material and trample it daily for several days so that the pods are broken, the seed is shed, and branch and pod material break into smaller fragments.
- Partly fill a 20-litre bucket with material and shake it from side to side so that the seed falls to the bottom.
- Discard the branch and pod fragments.
- Pass the seed and small fragments through one or more sieve sizes if needed to further clean the seed.
- For large quantities use a commercial seed cleaner.
- Store the seed in cold, low humidity conditions if possible.
- Otherwise, store seed in an air-tight container for up to several years (e.g., ice-cream container). NB: Weevil infestations do not seem to reduce the seed viability.

Seed germination

- Fresh seed may have a high hard seed content (>80%) and scarification is required to ensure that most of the seed germinates within a few weeks.
- Scarify the seed by rubbing the seed between two abrasive pads or use hot water (Appendix 6).
- Place seed into hot water just taken off the boil (85-90°C).
- Soak the seed for 12+ hrs.
- Select the seeds that have swollen and discard those that have not. Alternatively, repeat the hot water process with seeds that have not swollen.
- Sow 3 or 4 scarified seeds per cell directly into root trainers (Figure 7), or other containers filled with a commercial potting mix.
- Thin to one seedling per cell after the first two leaves have emerged.

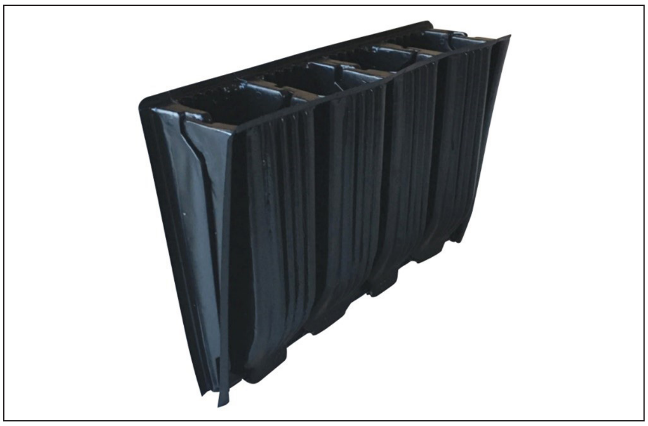


Figure 7: A four-cell root trainer.

Seedling growth

- Inoculate seedlings (or seeds) with N-fixing Rhizobium bacteria. The rhizobia used for lotus (*Lotus pedunculatus*) will also infect tagasaste and can be purchased from some seed companies.
- Alternatively, supplement the growing media with soil collected from beneath nodulated, healthy trees. (Nodules are small swellings on the roots in which the N-fixing rhizobia live).
- Although tagasaste may be infected by naturalised rhizobia in soils, inoculating seeds or seedlings ensures that rhizobia are present and fixing nitrogen as indicated by root nodules with healthy pink centres.
- Grow seedlings in a well-drained growing media.
- Ensure that seedlings are well-ventilated to reduce the risk of fungal disease and avoid growing them in a hot house or a poorly ventilated shade house.
- Water the plants daily.
- Transfer seedlings into larger containers if they outgrow the root trainers.

Seed collected in mid-December to mid-January and sown in autumn will produce seedlings that may be ready for planting out by late winter/early spring. However, seeds which are stored and then sown in spring will produce much larger seedlings before their first winter. Larger seedlings will increase establishment success.

Planting site preparation

Key aspects of site preparation before planting are controlling resident vegetation, correcting soil nutrient deficiencies and controlling pests.

The key steps of site preparation are:

- Remove the resident vegetation by hard grazing with livestock.
- Spot-spray the planting area (e.g., 1 m^2) 3-5 weeks before transplanting.
- Brushweeds such as blackberry (*Rubus fruticosus*) and gorse (*Ulex europaeus*) may require repeat herbicide applications for up to six months before planting seedlings.
- Correct soil nutrient deficiencies by applying fertiliser and lime up to six months before planting. Aim for a pH of 5.0-6.0 and Olsen P ≥20 ppm.
- Manage animal pests (e.g., hares, rabbits, possums and goats) with baits, net-guards, sleeves or chicken mesh during establishment.

Establishment by direct seeding

Direct drilling or broadcasting of seed is not recommended in New Zealand as tagasaste seedlings are outcompeted by resident vegetation or eaten by invertebrate pests (e.g., slugs and snails) and success rates are generally low (Appendix 7).

Scarified and inoculated tagasaste seed can be drilled into a cultivated or herbicide-treated pasture in spring when soil temperatures are increasing.

Tagasaste has been sown in late winter in lower rainfall areas and in early to mid-spring in higher rainfall areas. In Canterbury, seedlings grew more rapidly when sown in October and November than in September [20]. Tagasaste can be sown in early autumn when rainfall is reliable and there is a low frost-risk in the months following sowing. Bait can be used to control invertebrate pests.

In Canterbury, 12 weeks after a spring sowing, seedling emergence was 55% following drilling into cultivated ground and 40% when drilled into herbicide-treated pasture [20]. In contrast, drilling into short, mown pasture (25 mm height) or broadcasting on to short pasture treated with herbicide had <1% establishment success.

In Western Australia, sowing rates of 250-500 g/ha are recommended to achieve densities of one to two plants per metre when sowing in rows [35].

Establishment by transplanting

Transplant seedlings between autumn and spring but avoid the risk of severe frosts and droughts within several months of planting. In higher rainfall areas, planting in September or October enables plants to establish before summer.

Tagasaste establishment can take 12-24 months, during which time it cannot be grazed. Establishment by transplanting is much more successful than direct seeding and involves the following steps:

- Inoculate seedlings as described on page 15.
- Harden-off the seedlings before transplanting.
- Plant into well cultivated holes once seedlings are 30-50 cm tall and roots have filled the planter cell but before the plants have become root-bound.
- Trim taller seedlings to a height of 30-75 cm to encourage multiple branching which increases their tolerance to grazing (Appendix 8).
- Bare-rooted seedlings are cheaper than containerised plants. Store bare-rooted seedlings out of direct sunlight, keep them moist and ideally plant them within several days.
- Control weeds by hand or herbicide application during establishment.
- Control slugs and animal pests (hares, rabbits, possums, goats).

It is also possible to transplant seedlings that have grown beneath mature trees.

Unprotected trees can be established in a plantation or fenced area, or trees can be individually protected with tree-guards. Tree-guards enable livestock to continue grazing pastures and control weeds around the newly established trees.

If using tree-guards:

- Place a weed mat around the seedling, which can eliminate the need for herbicides.

- Erect the tree-guard to deter grazing by livestock, hares and rabbits.
- Remove tree-guards once the trees are aged between 3 and 4 years.

Plant spacing

Tagasaste trees may be planted close together in rows for shelter belts, as often seen in New Zealand. Shelter belts can be grown either as a single row or a double row with one row offset from the other for more complete shelter. A double row is more productive than a single row. In Western Australia, similar patterns of planting are often used for feed production and hedgerows are trimmed by machine to keep the growth within reach of livestock.

Trees may be planted at wider spacings, typically on hill country sites and trimmed occasionally for livestock browsing when managed to provide feed. Alternatively, trees may be left untrimmed and still serve several purposes when mature, including providing shade, erosion control and incidental browsing (Table 3).

Table 3: Plant spacing for tagasaste on farms.

Planting Style		Spacing (m)
Single Row		1-3
Double Row	Within row	2-3
	Between rows	1-2
Spaced Planting	Managed for feed (trimming)	4-6
	Unmanaged (no trimming)	8-10

Practical guidelines: Tagasaste management

Stands can be managed by cutting, grazing or a combination of both.

Grazing of unprotected trees within a fenced area:

- Exclude livestock for up to 24 months.
- After about 2 years, sometimes sooner, lambs or hoggets may be grazed around the trees with care.
- After 3 years, most trees will tolerate sheep browsing but trees should be monitored for damage.
- After 4 or 5 years, the trees will be able to withstand young cattle but should still be monitored for damage.

Grazing of trees protected with tree-guards:

- Carefully graze the pasture between the protected trees with sheep or young cattle.

Grazing of mature stands:

- Graze stands intermittently and leniently with cattle or sheep to remove up to 80% of leafy material to encourage leafy regrowth.
- Do not graze continuously as livestock may ring-bark and kill the plants.
- Use electric or permanent fences to protect the main trunks and to allow livestock to eat protruding branches. Virtual fences may become an option.
- To maximise regrowth, EDM production and forage utilisation, remove vegetation that has grown above the reach of livestock.

Cutting of mature stands:

- Use chainsaws, loppers or tractor-mounted saws where accessible.
- Trim trees 40 to 90 cm above the ground to keep the regrowth within grazing height.
- Trim the trees up to four times each year, depending on when the forage is required (e.g., end of summer drought).
- More frequent trimming can increase the dry matter harvested.
- Trees can be trimmed more frequently in summer to early autumn and less in winter, when growth slows. Trimming encourages leafy regrowth rather than woody stem growth and maximises EDM.

The effect of cutting on EDM depends on plant age/size, cutting height and management history and will vary further from farm to farm. For example, on sandy soils in Rangitikei, previously cut plants produced a similar amount of EDM over about 1 year regardless of whether they were cut once or twice (≈1.8 t EDM/ha) [18]. In contrast, in Manawatū on silt loam soils over the same period, plants cut twice (≈2.7 t EDM/ha) produced 27% less than those cut once (3.7 t EDM/ha).

Cutting may also lead to greater EDM production than from plants grazed intermittently. In Canterbury, plants with a history of cutting produced about twice as much as those that had been grazed (3.2 vs 1.8 kg DM/ha) [20].

Establishment costs

Note: The assumptions, calculations and figures used in this section are based on costs incurred on case study farms in Hawke's Bay in 2021 and are indicative only. Figures will vary depending on the location, production and labour costs. They provide a guide to help farmers estimate the establishment costs for their own farms. Note that it is possible to collect tagasaste seed and grow your own seedlings; this can reduce establishment costs.

Costings are presented for both establishing unprotected trees in a plantation and establishment for individually protected trees.

For both costings, it is assumed that seedlings are established at a uniform spacing of 8 m x 8 m (156 stems/ha) for the purposes of soil conservation and stock fodder on dry hill country.

Unprotected trees

The cost of establishing unprotected trees within a fenced paddock or plantation, including the seedlings, site preparation, labour and weed control, is estimated to be $860/ha (Table 4).

Table 4: Cost ($/ha) of establishing wide-spaced tagasaste without individual tree protection.

Item	Quantity	Price ($)	Total ($/ha)
Seedling purchase (8 m x 8 m spacing)	156	1.70	265
Spot spraying and labour:			
Glyphosate	1	5	5
Terbuthylazine	1	10	10
Labour	1	35	35
Planting (labour)	156	1	156
Follow-up releasing (Glufosinate and labour)	2	45	90
Weed control *	2	150	300
Total cost of establishment/ha			861

** In this situation, the main weed was blackberry.*

Protected trees

The cost of establishing protected trees in grazed pasture, including the seedlings, site preparation, tree-guards, labour and weed control, is estimated to be $5,570/ha (Tables 5 and 6).

A video showing how to construct a tree-guard suitable for tagasaste establishment can be found here: Tree Guard Video.

Table 5: Cost of tree-guard material ($/tree).

Material	Quantity	Price ($)	Total ($/ha)
Plastic net-guard	1	8.63	8.63
Y Post	1	7.57	7.57
Safety cap	1	0.39	0.39
Fibreglass rod	1	3.35	3.35
Cable ties	5	0.07	0.35
Weed mat	1	0.58	0.58
Fertiliser tablet	1	0.07	0.07
Total (rounded)			**21.00**

Table 6: Cost ($/ha) of establishing wide-spaced tagasaste with individual tree-guards.

Material	Quantity	Price ($)	Total ($/ha)
* Seedlings (8 m x 8 m spacing)	156	1.70	265
Tree-guard materials	156	21.00	3,276
Labour	156	13.00	2,028
Total cost of establishment/ha (rounded)			**5,570**

** Taller, wide-spaced soil conservation trees such as poplar, oak etc. would be planted at much wider spacings than 8m × 8m. Doubling the spacing to 16m × 16m reduces the cost of tree-guard use to $1,392/ha.*

Economic benefits

The economic benefits of tagasaste have been estimated for its feed value, N fixation, honey production and soil conservation. Estimates are based on a combination of experimental data from the Wairoa field site (Appendices 1–5), published literature, and prices of goods and services in Wairoa as of October 2021.

Feed value

The feed value of tagasaste is comparable to lucerne hay [36], which is valued at $85 per 320 kg DM bale, delivered ($0.27/kg DM) [37].

Assuming that the tagasaste:

- Production is 2.70 kg EDM/tree/yr (Appendix 1)
- Planting density is 156 sph (stems/ha) (Appendix 5)
- Total production is 2.70 x 156 = 421 kg DM/ha/yr
- Feed value is $0.27/kg DM.

Tagasaste feed can be valued at 421 x 0.27 = $114/ha/yr.

N fixation by tagasaste

In Australia, tagasaste trees planted in alleys at 550 sph fixed 83 kg N/ha/yr and at 2330 sph fixed 390 kg N/ha/yr [38]. This indicates N fixation rates of 0.16 kg N/stem/yr.

Assuming a stem density of 156 sph, the plantation may be fixing approximately 25 kg N/ha/yr (0.16 kg N/stem/yr x 156 sph).

The cost of applying 25 kg N/ha/yr in the form of urea in Wairoa comprises the cost of:

- Supply: $845/t ($1.84/kg N)
- Spreading by plane: $300/t ($0.65/kg N).

The total cost of spreading 25 kg N is: ($1.84 + $0.65) x 25 kg = $62/ha/yr.

Therefore, the estimated value of N fixation supplied by the tagasaste planting at Wairoa is $62/ha/yr.

Honey production

Tagasaste is valuable for beekeepers as it provides high protein pollen over a long flowering season [39]. Tagasaste flowers over 3 months in the Gisborne region, from July to September. If many hives can be maintained in the lead up to the main honey or pollination seasons, there is a significant economic benefit for beekeepers. Tagasaste stands can reduce the costs associated with beekeepers needing to provide their bees with protein feeds in late winter. According to Barry Foster, a Gisborne beekeeper and Trees for Bees advocate (pers. com., October 2021) the saving on purchasing protein feeds, driving to feed his bees, and the labour time involved is the equivalent of at least $20/feed/hive. This figure is based on protein feed requirements for two apiaries, each with 15 hives, and both apiaries within several kilometres of a plantation of tagasaste trees (400 sph) on a steep eroding face. Hives may require 3 or 4 purchased protein feeds over winter and into spring. In addition, Barry can spend his time doing other productive activities rather than providing protein feeds.

Based on this, it is estimated that if one apiary containing 15 hives was positioned near the hectare spaced planting (156 sph) of tagasaste at Wairoa, there could be an estimated benefit to the beekeeper of: $20/feed/hive x 15 hives = $300/feed/ha/yr.

The value of the total benefit could be much greater depending on the size of the tagasaste plantation, number of hives and the number of feeds per year that are no longer required due to the presence of flowering tagasaste stands.

Soil conservation and carbon sequestration

Soil conservation

It has been estimated that prevention of erosion may have an ecosystem service value of more than $250/ha/yr in the Hawke’s Bay region [40].

This was calculated as the value of the potential loss of sediment that could be avoided by tree planting. Calculations included the pre- and post-harvest erosion that occurs during a *Pinus radiata* rotation. Tagasaste differs from pines in that it is a small tree and will not be harvested so there will be no soil disturbance. However, as trees die, they must be replaced. Assuming a perennial tree cover without soil disturbance from harvesting, the value of erosion control from tagasaste could be higher than the figure above.

Further financial benefits

Shade and shelter provided by trees in the landscape (e.g., tagasaste) may contribute to livestock welfare and productivity, which can result in further economic benefits [10].

Additionally, having quality bee feed available [39] can encourage beekeepers to locate their hives on farms during winter. There are multiple benefits from this including increased pollination of annual clovers and seed crops near the tagasaste plantations, as highlighted by Doug Avery from Bonavaree Farm (See page 11).

In Australia, tagasaste planted on a site marginal for supporting pasture sequestered more than 20 t/ha/yr of soil organic carbon over 22 years, with another 35 t/ha/yr of biomass carbon [16]. However neither tagasaste nor soil carbon currently qualify for inclusion in the New Zealand Emissions Trading scheme (as at January 2022).

Summary

The direct on-site benefit of tagasaste on pastoral hill country comprises its estimated contribution to:

- Feed value: $114/ha/yr
- N fixation: $62/ha/yr
- Honey production: $300/feed/ha/yr
- Soil conservation: $250/ha/yr.

The total estimated benefit is $726/ha/yr.

Given an establishment cost of approximately $860/ha (unprotected individual trees, Table 4) and estimated production benefits of approximately $726/ha/yr from an established tagasaste planting, establishment costs would be recouped within several years of establishment.

Practical tips from experienced growers

Eight farmers and researchers from New Zealand and Australia with years of experience working with tagasaste were interviewed on their experiences in growing tagasaste. Below is a summary of their comments on its value, tips for successful establishment, management and difficulties encountered.

Value of tagasaste on-farm

- Fodder crop and can have high production with high nutritive value but requires careful grazing management.
- ‘Cut-and-carry’ at a small scale.
- Feed for kererū and tūī.
- Useful as a nurse crop for native plant establishment.
- Source of firewood and is a N fixer.
- Provides useful browse with intermittent lax grazing.
- Hedges provide feed and shelter for lambs and other livestock.
- Minimises parasite levels.

Tips for establishment success

- Start with small blocks of tagasaste before attempting large scale (hectares).
- Pre-spraying and weed control are needed at establishment.
- A tough plant – can be established without herbicides in a dry environment where competition with grass is not a problem.
- Plant on dry sites between September and November after the frosts have finished and in free-draining soils.
- Plant on steep faces but not in wet areas.

Tips on grazing management

- Should not be grazed until after two years’ growth.
- Do not graze too hard – graze young plants lightly to encourage branching.
- Plants must be given time to recover before the next grazing.
- Tagasaste suits being trimmed ‘hedge’ style and it is difficult to pollard older trees.
- Graze to reduce flowering over summer to get as much leafy growth as possible.

Difficulties in growing tagasaste

- Tagasaste is frost tender when young.
- Unsuitable for waterlogged environments.
- Sheep can strip bark from established trees.
- Rabbits and hares can damage seedlings.
- Attractive to birds which can bring weed seeds into a pasture.
- Potential as a weed in dry waste areas.

Frequently asked questions

What are the benefits for my livestock?

Tagasaste provides a high protein browse feed during droughts, as well as shade, shelter from the wind and a food source for pollinators, which can benefit lucerne and clover persistence and production. There are also many minerals in tagasaste which can supplement a pasture-based diet.

Where does it grow best?

Tagasaste grows best on drought-prone flat land and north-facing hill country. It can grow well in higher rainfall areas providing soils are free-draining.

Where won't it grow?

It will not persist when soils remain damp or waterlogged or where seedlings are exposed to heavy frosts.

How do I establish it?

Transplanting seedlings is best. It does not establish well from seed sown directly onto the hillside. Seedlings can be either individually protected within tree-guards with weed mat or else grown within a fenced area from which livestock and pest animals are excluded for the first few years (see page 16).

What are the costs?

Assuming seedlings are planted at a spacing of 8 m x 8 m (156 trees/ha), planting costs are estimated to be $860/ha without individual tree-guards and $5570/ha with tree-guards (see page 19-20).

How do you control weeds?

Spot-spraying removes vegetation before planting. A weed mat or follow-up herbicides can be used when planting seedlings to reduce the competition from grasses and weeds.

When can I graze the planted areas?

Pastures with seedlings which are individually protected with tree-guards can be grazed after planting. This must be done with care to ensure that livestock do not damage the tree-guards. Unprotected seedlings can be grazed with lambs after two years. Heavier sheep and cattle can be introduced four or five years after establishment, but always with care so that bark is not stripped from the trees which can cause irreparable damage.

Will it become weedy?

Tagasaste is unlikely to become weedy in most New Zealand environments. In disturbed areas, such as shingly riverbeds, it may grow into dense stands and interfere with nesting birds.

How much will it affect my pasture?

Pasture growth under constant heavy tagasaste shade may be reduced by up to two-thirds. Under light shade, pasture growth may be reduced by one-third. This is counter-balanced with other benefits such as providing drought feed, shade and shelter, feed for pollinators and controlling erosion.

What pasture species grow well in a pasture-tagasaste system?

Cocksfoot grows well in open pastures and in shade under tagasaste (Appendix 5).

Any disadvantages?

Tagasaste does not persist in continuously damp areas and is susceptible to borer insects. It is susceptible to overgrazing; animal pests can graze and easily kill seedlings during establishment. Tagasaste contains tannins which have potential anthelmintic properties, but tannins can also reduce palatability, feed intake and protein absorption. When tagasaste is used as browse and as a supplement to pasture, the negative impacts of tannins are unlikely to be a problem.

It has become weedy in disturbed sites in low rainfall areas in south-eastern Australia. This is not an issue in most New Zealand locations given the frequent occurrence of frosts and generally higher rainfall which limit its spread.

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Appendices

The Sustainable Farming Fund Project 'One Winter–Two Springs' Project No. 405641 (2018–2021) focused on growing tagasaste in grazed hill country pastures in East Coast North Island hill country. This included studies on estimating tagasaste EDM production, forage quality and mineral content undertaken near Wairoa in northern Hawke's Bay (Appendices 1–4). A major focus of the project was on quantifying the production of a range of pasture species which were transplanted into open pasture, light tagasaste shade and heavy tagasaste shade at the Wairoa field site (Appendix 5). We also researched tagasaste seed germination and seedling management, including research on seed treatments to improve germination under controlled conditions at Ruakura Research Centre in Waikato (Appendix 6), direct seeding of tagasaste into Waikato hill country (Appendix 7) and the effects of trimming height on tagasaste branching in a pot study at Ruakura Research Centre (Appendix 8).

1. Estimating edible dry matter production

8a: A tagasaste tree before trimming (March 2021).

8b: A tagasaste tree after trimming (March 2021).

8c: A view of the fenced field site in March 2020. Note the spaced tagasaste plants, protected by tree-guards, growing on the grazed hillslope surrounding the field site.

Figure 8: Estimating edible dry matter production.

On a steep, north-facing slope in Hawke's Bay, a tagasaste plantation was established to quantify seasonal and total annual edible dry matter (EDM). The tagasaste was established at a spacing of 3 m which was equivalent of 1100 stems/ha and fenced to exclude livestock (Figure 8). Three years after establishment, the trees were trimmed every 6-12 weeks for 12 months. Under-canopy pastures were trimmed with a weed-eater once each season.

- The trimming regime removed most green leaf at each harvest and production of flowers and seedpods was negligible.
- Flowers and seeds comprised 4% of the annual total EDM.
- Each tree produced ≈2.70 kg EDM per year, with lowest EDM occurring in autumn (Figure 9).

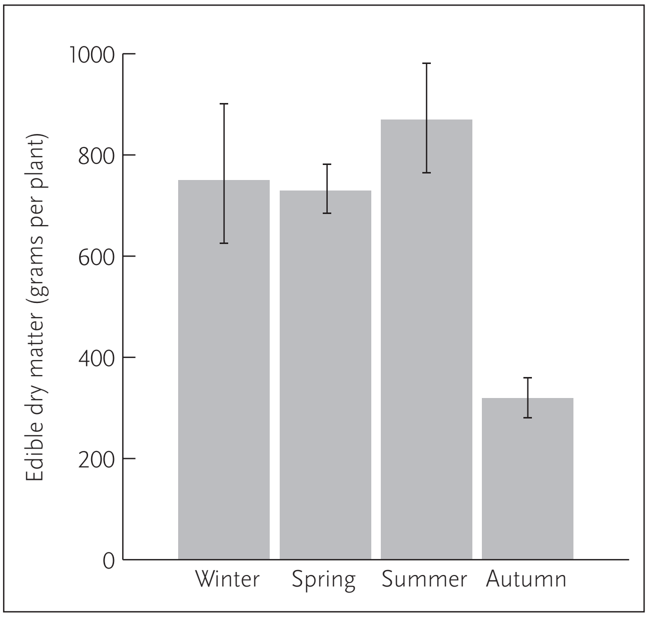


Figure 9: Seasonal edible dry matter production (leaf and stem <5 mm diameter) of 3-year-old tagasaste trees grown on a north-facing slope in northern Hawke's Bay. Data were collected over one year. Bars are standard errors of the mean. *Winter: June-August; spring: September-November; summer: December-February; autumn: March-May.*

2. Estimating edible dry matter from tagasaste branch length and diameter

There was a statistically significant relationship between tagasaste branch diameter and edible dry matter (EDM) (P<0.01). However, the overall association between branch diameter and EDM was low; only 16% of the variation in EDM could be explained by branch diameter (Figure 10a). There was also little relationship between branch length and EDM.

The results were obtained by measuring 48 different branches on 8 occasions over 12 months in two established tagasaste plantations on steep, north-facing slopes in Hawke's Bay.

Tagasaste trees were closely spaced and growth was affected by shading (Figure 10b, 10c). Wider spacings and straighter branches may be required for associations between branch characteristics and EDM to be detected, as has occurred for poplar and willow.

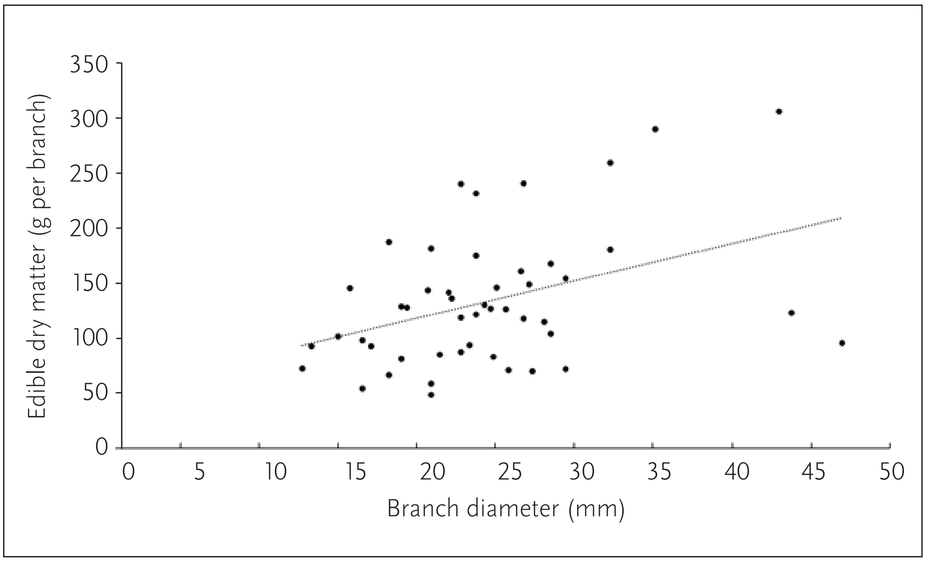


Figure 10a: Relationship between edible dry matter per branch and branch diameter for branches sampled at 6 weekly intervals from established tagasaste trees on two steep, north-facing slopes in Hawke's Bay from November 2018 to December 2019.

Figure 10b: One of the branches for which edible dry matter production was estimated.

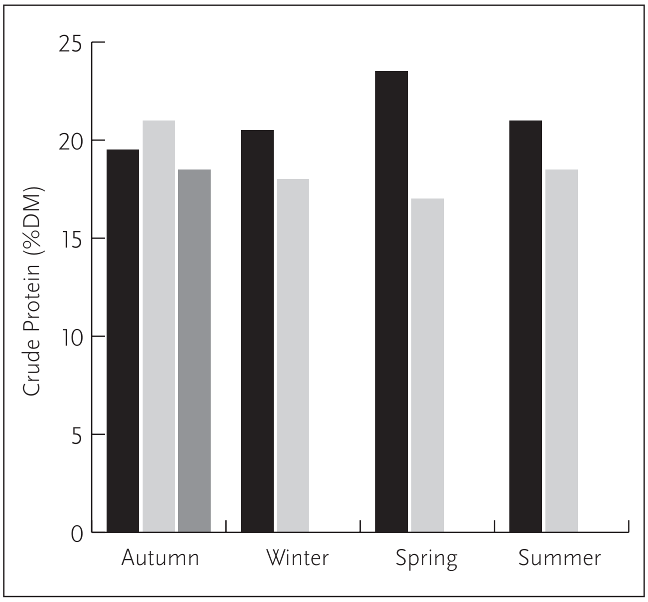
Figure 10c: The trees were closely spaced and growth was affected by shading, which most likely reduced the association between branch diameter and edible dry matter.

3. Tagasaste nutritive value

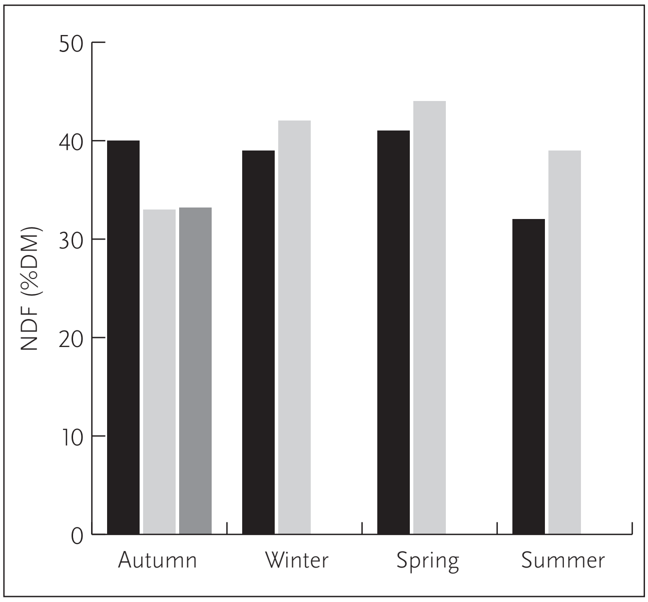
On a steep, north-facing slope in Hawke's Bay, the nutritive value of edible foliage from mature tagasaste trees between March 2019 and March 2021 was:

- Crude protein: 17% to 23% (Figure 11a).
- Neutral detergent fibre: 32% to 43% (Figure 11b).
- Metabolisable energy: 9.4-10.7 MJ/kg DM (Figure 11c). This is similar to values for perennial ryegrass during summer and autumn but lower than values typical of white clover and red clover.

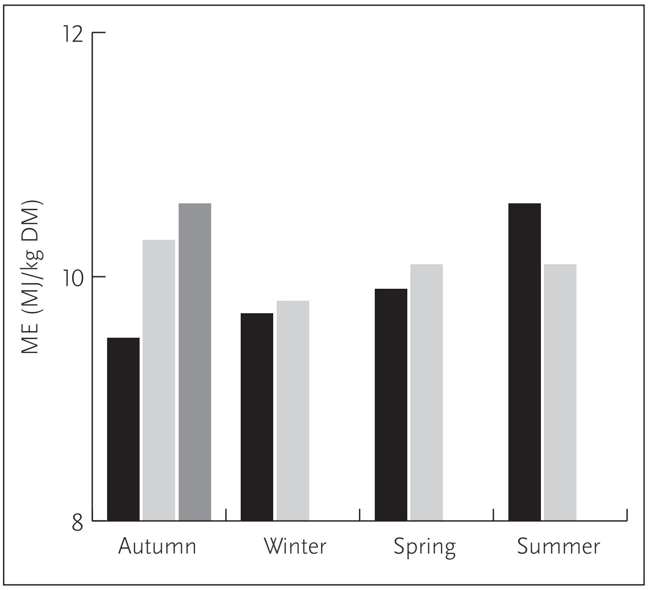
Analyses were conducted using wet chemistry.



11a: Mean contents of crude protein.



11b: Mean contents of neutral detergent fibre.



11c: Mean contents of metabolisable energy (ME).

KEY:

2019 2020 2021

Figure 11: Mean contents of crude protein, neutral detergent fibre and metabolisable energy (ME) in edible foliage (leaf + stem <5 mm) of tagasaste near Wairoa, Hawke's Bay, between autumn 2019 and autumn 2021. *Winter: June-August; spring: September-November; summer: December-February; autumn: March-May.*

4. Concentrations of minerals in tagasaste

On a steep, north-facing slope in Hawke's Bay, the mean concentrations of minerals in tagasaste edible DM exceeded those recommended for sheep/cattle, except for phosphorus which was marginal for sheep in summer and autumn, and marginal for cattle in winter and spring (Table 7).

Table 7: Mean seasonal concentrations of ash (which contains the total amount of minerals present) and individual minerals in edible foliage (leaf + stem <5 mm) of tagasaste on a steep, north-facing slope in Hawke's Bay over the period 2019-2021.

Component	Spring	Summer	Autumn	Winter	Recommended [3]
Ash [1]	6	4.7	5.3	6.2	
Phosphorus [1]	0.23	0.17	0.17	0.22	0.20/0.32
Potassium [1]	1.38	1.23	1.13	1.38	0.36/0.58
Calcium [1]	0.58	0.54	0.46	0.45	0.29/0.44
Magnesium [1]	0.32	0.37	0.29	0.25	0.12/0.19
Sodium [1]	0.16	0.13	0.16	0.18	0.09/0.12
Copper [2]	8	10	8	7	5/7-10
Iron [2]	149	147	143	118	30/40
Manganese [2]	181	188	144	164	25/25
Zinc [2]	39	40	36	39	25/25

[1] % of dry matter (DM); [2] mg/kg DM; [3] Levels in pasture for an adequate mineral intake for grazing sheep/cattle [33, 34].

5. What pasture species grow best in combination with tagasaste?

On a steep (30°), north-facing slope in Hawke's Bay, the growth of pasture species when grown beneath tagasaste trees and in adjacent open pasture was quantified (Figure 12).

- The planting density was 156 stems/ha (sph).
- There were three shade treatments: heavy shade, light shade and open pasture. Heavy shade was within 1 m of a tagasaste trunk, light shade within 1-2 m of a trunk and open pasture was between trees and not directly under the canopy of a tagasaste tree.
- Species tested include perennial ryegrass, cocksfoot, rice grass (*Microlaena stipoides*), prairie grass, white clover, red clover and lotus.
- Photosynthetically active radiation was reduced by approximately 75% in the heavy shade treatment and 40% in the light shade treatment when compared to open pasture (Figure 13).
- Shading reduced herbage production of spaced plants; total annual herbage production per plant was reduced in heavy shade by about 70% when compared to open pasture (Figure 14).
- Topsoil moisture content was lower in the heavy and light shade treatments than in open pasture on one occasion over the 12 months (Figure 15).
- By March 2021, approximately 2.5 years after transplanting:
    - Survival was much higher for the grasses (averaging 84%) than the legumes (28%).
    - Cocksfoot performed the best of the grass species regardless of the shade treatment with the highest survival and herbage production and a high metabolisable energy (Figure 16 and Figure 17). It suffered little damage from insect pests and diseases. The cocksfoot cultivar was a newer cultivar that is more palatable than older cultivars which often become clumpy and are avoided by livestock.
    - Lotus performed the best of the legumes. It had the highest survival, high herbage production, provided high metabolisable energy, and suffered low levels of damage from insect pests and diseases.

12a: Field site established to quantify the growth of pasture species when grown beneath and between established tagasaste trees.

12b: Spaced pasture plants.

Figure 12: Pasture species growing below tagasaste.

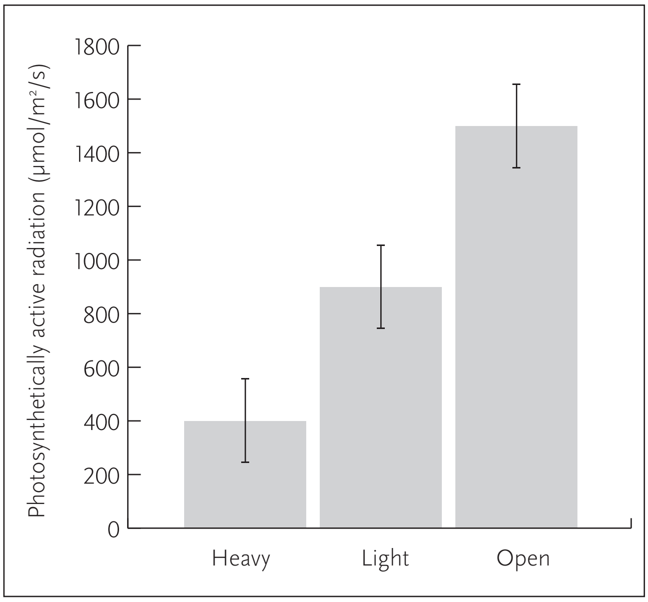


Figure 13: Photosynthetically active radiation 30 cm above the ground surface (1 July 2019 – 30 June 2020) in heavy and light tagasaste shade, and adjacent open pasture, on a steep, north-facing slope. Bars are standard error of the mean.

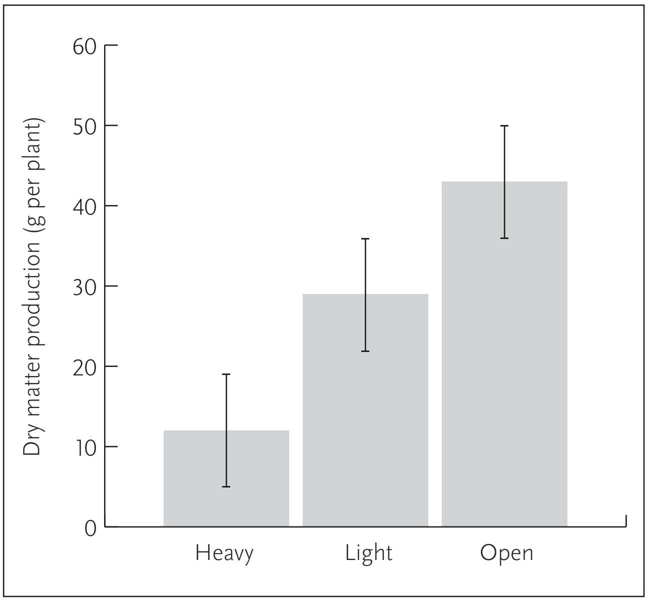


Figure 14: Mean total annual herbage production (1 July 2019 – 30 June 2020) for a range of pasture species grown in heavy and light tagasaste shade, and adjacent open pasture, on a steep, north-facing slope. Data are averaged over all species for each shade treatment. Bars are standard error of the mean.

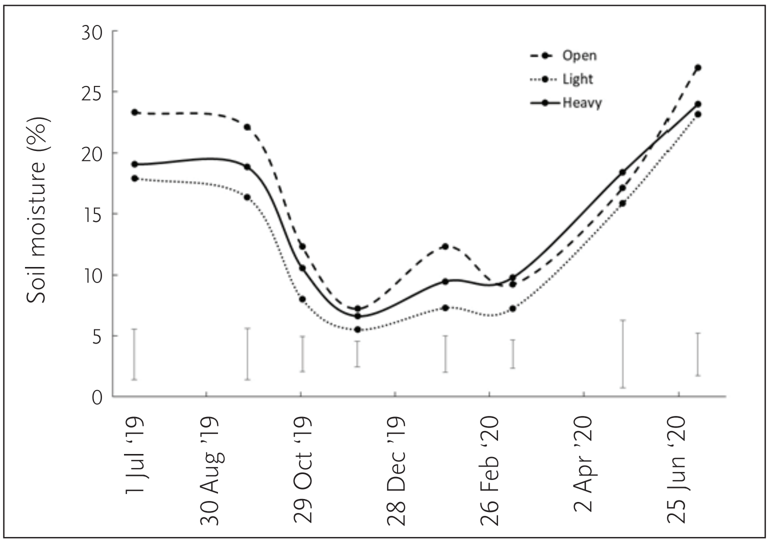


Figure 15: Temporal changes in soil moisture content (%, 0 – 12 cm depth) in heavy and light tagasaste shade, and adjacent open pasture, on a steep, north-facing slope. Bars are standard error of the mean.

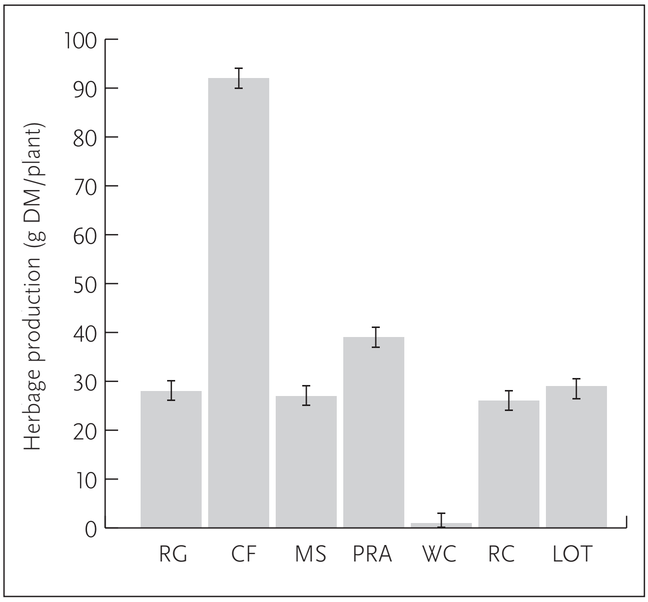


Figure 16: Mean total annual herbage production in the second year (1 July 2019 – 30 June 2020) for pasture species grown as spaced plants on a steep, north-facing slope. Data are averaged over heavy tagasaste shade, light tagasaste shade and adjacent open pasture treatments. RG: perennial ryegrass; CF: cocksfoot; MS: rice grass (*Microlaena stipoides*); PRA: prairie grass; WC: white clover; RC: red clover; LOT: lotus. Bars are standard error of the mean.

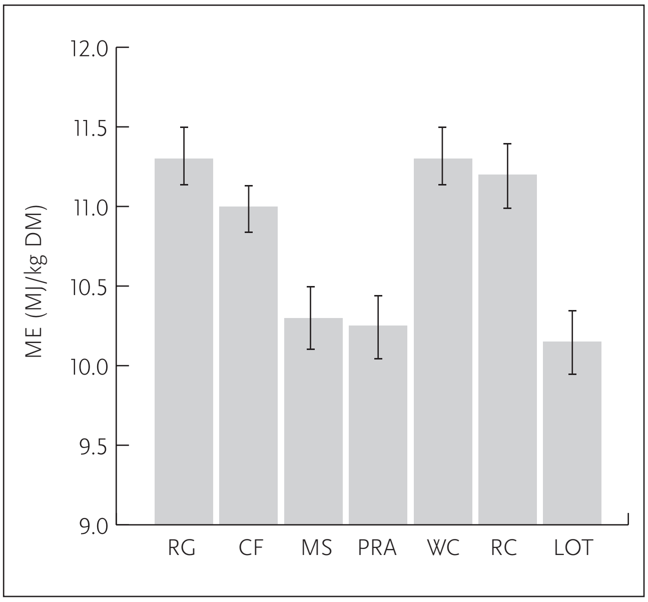


Figure 17: Metabolisable energy (ME) content for pasture species grown in heavy and light tagasaste shade, and adjacent open pasture, on a steep, north-facing slope, averaged over 3 years from spring 2018 until autumn 2021. RG: perennial ryegrass; CF: cocksfoot; MS: rice grass (*Microlaena stipoides*); PRA: prairie grass; WC: white clover; RC: red clover; LOT: lotus. Bars are standard error of the mean.

6. How to germinate tagasaste seeds

Tagasaste has a hard seed coat which prevents germination. Scarification is needed to break the hard seed coat for germination.

Different seed scarification methods were compared under controlled conditions at Ruakura Research Centre, Waikato:

- Application of gibberellic acid
- Application of potassium nitrate
- Nicking the seeds and soaking them in warm tap water (38^{0}C) and left to cool overnight (≈18 hrs)
- Cold tap water was used as the control.

A total of 150 seeds were tested for each method. After the scarification treatment was applied, all seeds were laid between two layers of moist filter paper in a sealed bag and maintained at 25^{0}C for six weeks with a day length of 16 hr.

Gibberellic acid and potassium nitrate did not penetrate the hard seed coat and germination was negligible. The highest germination percentage occurred from the nicking + warm water treatment (68% vs. <1% for all other treatments, $P<0.001$).

A subsequent study compared the use of hot water with and without nicking:

- Placing seeds into water that had just been boiled and then left to cool overnight
- Nicking + warm tap water (38^{0}C)
- Cold tap water was used as the control.

Three weeks after treatment application, the germination percentage of tagasaste was similar for the heated water treatments (≈40% germination). Only 10% of the seeds in the control treatment had germinated. There was negligible germination of seed between 3 and 5 weeks after treatment application for all treatments (Figure 18).

Placing seeds into water that has just been boiled and then left to cool overnight is a simple and effective method of scarifying the seed coat and germinating tagasaste seed.

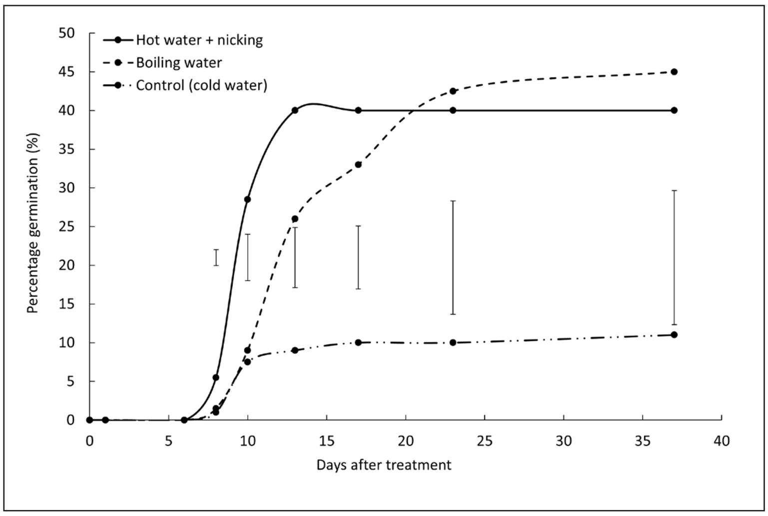


Figure 18: Germination of tagasaste seed placed in boiling water and left to cool overnight, nicked and placed in hot tap water (38°C) and left to cool overnight (same as in the previous study), and cold water which was used as the control. Bars are standard error of the mean.

7. Direct seeding of bare tagasaste seed on hill country

The effects of four treatments on tagasaste seedling growth and survival were compared on a north-facing slope in Waikato. Treatments were:

- Fertiliser (500 kg/ha diammonium phosphate (DAP) at sowing)
- Slug bait (10 kg/ha at sowing)
- Rhizobia application (slurry of lotus inoculant mixed with seed)
- Untreated control (no fertiliser, slug bait or rhizobia).

In each treatment, there were 4 replicates of 100 seeds (= 400 seeds per treatment) which were hand-sown on a north-facing Waikato hillside with an average slope of 12°. Glyphosate 540 (active ingredient: 540 g/L glyphosate at 1/L ha) had been applied to suppress grass growth 8 days before seeds were sown. The trial area was fenced to exclude grazing livestock and pests (e.g., rabbits, goats).

The first seedling was observed 3 weeks after sowing. An average of 6 seedlings per treatment were present 7 weeks after sowing (Table 8) and a total of only 2 seedlings were present at the field site 13 weeks after sowing.

Total seedling emergence was similar across treatments ($P>0.05$) and averaged 1.4% of the total number of seeds sown.

Slugs were present at the site and likely contributed to seedling mortality. Establishing tagasaste in resident pastures in summer-wet hill country is unlikely to be successful from sowing seed.

Table 8: Effect of fertiliser, rhizobia and slug bait on the total number of emerged tagasaste seedlings for up to 7 weeks after hand-sowing seeds (400 per treatment) on a north-facing hillside in Waikato. Control treatment: no fertiliser, rhizobia or slug bait.

Days after sowing	Control	+Fertiliser	+Rhizobia	+Slug bait
21	1	0	0	0
30	8	2	4	6
49	9	4	3	6

8. Producing multi-stemmed tagasaste shrubs

The effect of cutting the main stem (to remove 20%, 40%, 60% or 80% of the height of the seedling; average height 45 cm) on multiple-stem production and regrowth was quantified in a pot study at Ruakura Research Centre, Waikato (Figure 19). By 85 days after cutting:

- There was no effect of defoliation treatment on the number of stems produced from where the plant was cut (averaging 3 stems/plant).
- Removing 20% or 40% of the seedling height produced 3-fold greater above-ground EDM than when 80% of the seedling height was removed ($P<0.001$).

Removing 20% or 40% of the main stem resulted in the greatest regrowth. In contrast, defoliating the seedlings severely (80%) compromised regrowth and had no benefits for increasing the branch number when compared to removal of the top 20% or 40%.

Figure 19: Effect of defoliation on tagasaste seedling stem number and regrowth 85 days after treatments were applied. From left to right for the four pots at the front: 20%, 60%, 80% and 40% of the height of the seedling removed.