The commercialisation of kōkihi or New Zealand spinach (*Tetragonia tetragonioides)* in New Zealand

N. Roskruge
Institute of Natural Resources PN433, Massey University, Private Bag 11-222, Palmerston North 4442, New Zealand

Abstract

Kōkihi (*Tetragonia tetragonioides*) is the traditional name applied to the succulent green plant commonly called New Zealand spinach. It is a wild plant which grows in localised pockets along the coasts of both the North and South Islands of New Zealand, Stewart Island and Kermadec Island but it is seldom found naturally in inland areas. Commercially kōkihi is not a widely cultivated crop in New Zealand, however it is relatively common in non-commercial gardens and seed is available in garden centres. Scoping research was undertaken looking at a selection of agronomic factors which apply to this crop in a commercial production system. Kōkihi is susceptible to a minor range of pests and diseases including the fungal diseases *Uredo novae-zealandiae* (rust) and *Helminthosporium* sp. (commonly known as silver scurf on potatoes). The relationship of these diseases to other crops will influence the inclusion of NZ spinach in any crop rotation. Management of the plant is otherwise relatively simple and may be well suited to commercial opportunities.

Additional keywords: leafy vegetable

Introduction

New Zealand is the southernmost landmass of the Pacific Ocean and of the Pacific cultures. As such it endures a relatively temperate climate but does have extremes from sub-tropical in the north to sub-Antarctic in the south. Māori are the indigenous people of Aotearoa-New Zealand and as '*tangata whenua*' (literally 'the people of the land') they have created an enduring relationship with the landscape, including the flora and fauna which survives upon it. Among the plants which Māori had access to was kōkihi, commonly known as New Zealand (NZ) spinach (*Tetragonia tetragonioides*) which remains a favoured food source for many Māori with a variety of uses.

Tetragonia tetragonioides has been given the dubious recognition as possibly the only 'true' vegetable Australasia has provided to the world cuisine. This occurred through the actions of Captain James Cook and his botanist Joseph Banks in their exploits of the mid-eighteenth century. Traditionally kōkihi was not a cultivated crop by early Māori; however it was occasionally harvested from the wild and had several uses (Roskruge, 2007). Today most consumers of kōkihi source the plants from small cultivations or home gardens however, as demand for it increases there is growing interest from horticultural producers to include it in their suite of commercial crops produced for fresh markets. It is now being viewed as a

potential commercial crop option and the seed is also available to home gardeners.

Botanical status, nomenclature and distribution of kōkihi

Kōkihi or New Zealand spinach (*Tetragonia tetragonioides* (Pall.) Ktze, formerly *T. expansa* Murr. and including the archaic names *Demidovia tetragonioides, T. halimifolia, T. cornuta* and *T. inermis*) is native to New Zealand, Australia (including Norfolk Island and Lord Howe Island) (Cheeseman, 1925), Japan and the temperate regions of South America (Allan, 1961; Haase, 1990), specifically Argentina and Chile. *Tetragonia trigyna* (archaically: *T. implexicoma* var. *chathamica*) (Allan, 1961; Haase, 1990) is commonly called 'climbing New Zealand spinach' and is closely related but with smaller leaves and stems (Wall and Allan, 1950). Both plants have prostrate habits with leaves that turn red in strong sunlight. The name kōkihi is the preferred term now in contemporary usage and is understood to refer to both species across all tribal regions of New Zealand. Kōkihi is considered as an indigenous vegetable or food by many New Zealanders. It is a wild plant which grows in coastal areas throughout New Zealand and on off-shore islands including the Kermadecs (Sykes, 1977).

The genus *Tetragonia* includes about 60 species of flowering plants. They are mostly succulents found in the Southern Hemisphere, especially South Africa, and belong to the *Aizoaceae* family. The generic name *Tetragonia* comes from the Greek '*tetra'* meaning four and the suffix '*gonia'* meaning angles (Wall and Allan, 1950). This is in reference to the shape of the fruits of the plant which are generally four sided with angular shapes.

Records of the plant being promoted as a vegetable extend back to the first British settlers at Botany Bay (Sydney) of 1788 (Smith, 1998). NZ spinach was illustrated in the 1822 volume (50) of Curtis's Botanical Magazine, an authoritative horticultural magazine first published in London in 1787 (Matthews, 1977). The first record of NZ spinach being commercially available in England is when London seed suppliers Flanagan & Nutting offered 'New Zealand spinach or *Tetragonia expansa*' in their 1835 catalogue (Smith, 1998). From England, NZ spinach has been disseminated across Europe and is now grown both commercially and as a home garden vegetable in many cultures. Information to support the production of this plant can be found in many countries and languages including Serbia where it is known as *Novozelandski spanac* and France where it has several synonyms. It is grown commercially in countries such as Israel, where it is also an export crop (Duncan, 2004). Prakash (1967) describes the plant as an annual herb with a diffuse trailing habit. It is apparently a relatively common vegetable in India and featured in the Botanic Gardens of the University of Delhi, India. In the USA, NZ spinach is first recorded with the distribution of its seed among members of the New York Horticultural Society in 1827 followed by its appearance in seed catalogues in 1828 (Hedrick, 1919). It is both a commercial crop and one that is considered as an invasive weed in some coastal states such as California (Anon, 2008; Stephens, 2003). In Central and Latin America, NZ spinach is a well-known and popular vegetable. It is well suited to the heat of the tropical climate and copes with being regularly harvested over a long period of time. It is variously known in each language as NZ

spinach (Table 1) and is appreciated for its minimal management needs. It was recorded in the nineteenth century by St Hiliare for its use as 'spinach' in Southern Brazil (Hedrick, 1919) and is now commercially grown in many countries of this region including Brazil and Costa Rica. *Tetragonia tetragonioides* is also native to Japan and included in the Japanese diet although it tends to be referred to as NZ spinach rather than the native term Tsuruna. It is possible to find NZ spinach on the menu is such diverse locations as Morocco, Madagascar, Israel and China (Vietmeyer, 1991).

The plant is favoured for its leaves which are used for soups, cooked salads and stir fry's. Information to support the production of this plant can be found in many countries and languages (Table 1).

Table 1: Nomenclature for *Tetragonia tetragonioides* (Pall.) Ktze (formerly *T. expansa* Murr.).

Nomenclature for *Tetragonia tetragonioides*	
Māori (New Zealand)	Kōkihi; Paraihia; Tutae-ika-moana; Rengamutu; Rengarenga
English	New Zealand spinach; sea spinach; perpetual spinach
Australian colloquial names	Warrigal greens; Warrigal cabbage; Warrigal spinach; Botany Bay Greens; Sydney Greens
Polish[1]	Szpinak Nowozelandzki
Norwegian[1]	Ny-Zealandsk Spinat
Italian[1]	Spinacio della Nouva Zelanda
Spanish[1]	Espinaca de Nueva Zelandia
Africaans[1]	Nu Zeeland Spinasie
Hungarian[1]	Ujzélandi paraj
Croatian[1]	Novozealandski shpinat
Russian[1]	Novozelandskii Shpinat; Tetragonia Shpinatnaia
Swedish[1]	Nyzeeländsk Spenat
Greek[1]	Spanaki Neas Zilandias
Servian[1]	Novozelandski Spanac(h)
Slovenian[1]	Novozelandska Shpinacha
Danish[1]	Newzealandsk Spinat
Dutch[1]	Nieuwzeelandse Spinazie
Portuguese[1]	Espinafre De Nova Zelândia
French[1]	Tétragone; Tétragone Cornue; Epinard; Tetragon
German[1]	Neuseeländischer Spinat
German (Switzerland)[1]	Neuseeländer-Spinat
Brazil[1]; Costa Rica	Espinafre Da Nova Zelândia
Guatemala (Vietmeyer, 1991)	Spinaca Nuevo Zelandia
Japanese[1]	Tsuruna
Chinese	Xin Xi Lan Bo Cai*; summer spinach; Yeung poh tsoi
Philippines (Vietmeyer, 1991)	Baguio spinach

(Source: the Māori, English and Australian vernacular terms are colloquial; [1]www.zipcodezoo.com).

Current agronomic knowledge of kōkihi production

Kōkihi grows freely in a wide range of soils and climates primarily aligned to warm sandy sites including some relatively inhospitable islands such as Women's Island (Johnson, 1976) in the southern sub-Antarctic ocean. McLuckie and McKee (1962) describe it as one of only a few specialised plants that grows on sandy

beaches throughout New Zealand. Kōkihi is also a native plant in Australia, and generally known as Warrigal spinach; it is described as a perennial plant found on the coast and also inland dry areas but can be grown as an annual in cooler places. Furthermore, it is described as a plant that prefers temperate to sub-tropical climates, adapts to hot, dry and sandy soils and resists salt spray. The plant is suited to a wide range of soils including 'poor' and saline soils (Watkins *et al*., 1988); but prefers alkaline soils with a pH of between 6.5-7.5 and it tolerates maritime exposures. Recent international research has looked at the tolerance of *Tetragonia* sp. to saline soils. Wilson *et al*. (2000) investigated saline tolerance at different growth stages of the plant and determined *Tetragonia* spp. are still sensitive to saline during their juvenile stages, however they gained tolerance as the plant matured. Similar research by Watkins *et al*. (1988) suggested *Tetragonia* spp. are a marginal halophyte similar to other salt tolerant, non-halophytic plants.

Kōkihi can establish at any time of the year in New Zealand but prefers warm and frost-free sites. It is a coastal plant by preference and in some regions such as Taranaki is an everyday vegetable, grown in gardens and harvested on demand. The plant can grow up to 1m height and spread up to 2 metres. The tips of young plants are preferred for most uses as they are milder in flavour. By harvesting stem tips plants can be harvested with regularity over the whole summer-autumn period. Commercial growers harvest the whole juvenile plants as a single cut followed by replanting. The reliability of kōkihi as an available green vegetable plant throughout most of the year has perpetuated its usefulness in the New Zealand diet. Coincidentally, the resurgent interest in niche crops such as kōkihi has raised its potential to contribute to the commercialisation of the crop.

Materials and Methods

Crop production parameters

Trial crops of NZ Spinach were grown during the summer months of 2009-10 and 2010-11 at the crop unit at Massey University, Batchelar's Road, Palmerston North (40°22'40"S; 175°36'27"E) at an elevation of approximately 35 m. The soils are a recent Manawatu Silt loam, free draining, with a history of vegetable crop trials including taewa (Maori potatoes) in 2009 and Indian corn in 2007. The preceding crops were monitored for their relationship to soil factors and plant health issues; therefore the site is well understood around potential pathogen threats or soil limitations. Soil tests results gave a pH 5.8; 6.2 and 6.5 respectively in sub-blocks within the trial site. All other soil nutrient factors were in the median range for vegetable production. An additional banded application of 12:10:10 fertiliser was applied at 250 kg ha^{-1} during planting.

Transplants (40-45 days post-sowing) were planted beginning in late spring each season; one trial in each pH sub-block. Table 2 identifies the parameters applied to the trials which were based on the limited information available on their application in a commercially orientated system and the general parameters applied to some other prostrate crops. Observations were undertaken at least twice weekly over a period of 4 months to determine the growth habits and demands by the crop that may be made in a commercial production system.

Table 2: Production notes for *Tetragonia tetragonioides*.

Production factor	Notes
Planted as transplants: 40-45 days old.	Germination very irregular and transplants encourage consistent establishment in-field.
Sowing dates 2-3 weekly from early spring (September).	Transplants produced for planting out.
Planting from 40-45 days as transplants for one-off harvesting.	Single harvest of each plant at approximately 50 days from planting (late spring) to 70 days (summer).
Plant spacing: in-row 0.5-0.75 m between rows 0.8-1.0 m.	Spacing based on industry norm for bush pumpkins which have a prostrate growth habit.
pH 5.8-7.5.	Alkaline preference, lime as required.
Fertiliser: banded application of 12:10:10.	To support establishment.
Irrigation: applied regularly through summer.	Key component of plant integrity and quality.
Weed management: cultural and chemical.	Stale seedbed method applied.
Production season.	Market driven - potentially all year.

Results and Discussion

Crop establishment

The natural environment for the plant is on warm sandy soils, free-draining and with an aspect exposed to the sun for a majority of the day. A pH of between 6.5 and 7.5 was identified in the literature (Watkins *et al*., 1988; Wallace, 2000; Wilson *et al.*, 2000; Stephens, 2003) with the plant appearing to prefer more alkaline soils. These trials included a crop at pH 5.8 which was harvested at the same time as the other trials therefore indicating a broader pH range from 5.8-7.5 is possible. Further research on the relationship between soil factors and crop establishment is necessary.

The seed viability in non-commercial production indicates variable time periods to achieve germination (<20 days) thus creating a preference to produce transplants for planting out to ensure a consistent single harvest. Late maturing plants produce an abundance of seed which, if allowed to harden and separate from the plant, can be stored and used in subsequent plantings to meet production demands. Caution needs to be applied however as NZ spinach is noted in many countries as a common weed species in cropping situations. Currently there is no specialised NZ spinach seed production in New Zealand and further seed testing is planned.

Plant spacing can be manipulated based on harvest systems and also tractor tyre width. The plant spacing, both in-row and between-rows, needs to allow for the prostrate growth habit of the plant and access for machinery or harvest. The parameters trialled were based firstly on those applied to other sprawling vegetables (primarily cucurbits) grown in summer months on flat ground and secondly the growth rates observed for NZ spinach in the 2009 trial. A once-only harvest of the entire plant was undertaken based initially on feedback from small producers who indicated the plant turned woody relatively quickly if only partially harvested. This was supported by production criteria offered by off-shore producers. At 50-55 days post-planting the trial plants had achieved ground cover and were considered suitable

for harvest. As the crop is targeted for a single harvest there is no need to return to the area several times, thus minimising the potential damage to crops through multiple cuttings. At approximately 59-63 days from planting the first flowers were observed across all trials. This trait is considered undesirable for the market. The plant flowers and sets fruit easily so late maturing plants can be utilised for seed production if required.

Weed issues

There are no weed issues of concern for producers of NZ spinach other than the generic management of production sites to allow the plant to establish its dominance over an area. The use of the stale seedbed method for ground preparation supported by a pre-emergence herbicide is also advantageous in minimising weed competition during crop establishment. As a short-term annual plant with a prostrate and sprawling habit it tends to self-manage weed problems. There are currently no agrichemical label claims for weed control in this crop in New Zealand. In fact, most literature and herbicide claims refer to NZ spinach as a target weed species rather than as a crop plant.

Pest and disease issues

There are few known problems identified with the species however it is known for its susceptibility to a range of viruses including the Potato Andean mottle comovirus and Beet leaf curl rhabdovirus (EPPO, 2011), both of which have not yet been recorded in New Zealand. Other viruses have been mechanically applied to the plant in research in several countries resulting in a considerable number of known susceptibilities, all of which can be tested for in commercial situations. In Hawai'i the *mosaic virus* has been associated with *T. tetragonioides* but is not considered an economic issue (HEAR, 2011).

Within New Zealand the primary disease issue for this crop is the rust fungus *Puccinia tetragonia misdet.* renamed *Uredo novae-zelandiae* (McNab, 1966; Dingley, 1969; McKenzie, 1998). *Tetragonia* spp. is the primary host for this species of rust. Although this disease does not kill the plant, rust pustules on the leaves render them unmarketable and unusable. This disease was not observed in the trial crop, possibly because the plants were harvested relatively early in the season.

A number of fungal diseases identified in international literature for their pathogenic relationship to *Tetragonia* sp. are present in New Zealand. These include: *Alternaria alternata* (ex: *A. tenuis*), a storage rot considered of minor economic importance; *Botrytis cinerea* is a broad spectrum rot; *Cercospora* sp., a leaf spot fungus; *Helminthosporium* sp., commonly known as silver scurf in potatoes; and *Verticillium alboatrum*, a wilt disease found on potatoes (Duncan, 2004). The association of at least two fungal diseases that are found on potatoes implies good practice for this crop would be to grow it independently of potato crops rather than in neighbouring land or in close rotation.

International research has identified the field root knot nematode (*Meloidogyne hapla*) and glasshouse root knot nematode (*Meloidogyne incognita*) as parasitic pathogens of NZ spinach, affecting the roots of the plants in infected soils and causing ill-thrift, root galls and a loss of yield (Duncan, 2004). *Meloidogyne hapla* is a recognised parasitic nematode on tamarillo (*Cyphomandra betacea* (Cav.) Sendtner) and kiwifruit (*Actinidia deliciosa* C.F.Liang & A.R.Ferguson) crops (Knight,

2001) in New Zealand. This pathogenic relationship has been neither observed nor studied on kōkihi in New Zealand at this time however it is worth noting for the implications to producers.

Although not observed on these trials, aphids are recognised as a pest on kōkihi, specifically the melon aphid (*Aphis gossypii* Glover) and Green peach aphid (*Myzus persicae* Sulzer), both of which are prevalent in New Zealand (Knight, 2001). Heavy aphid infestations can deform leaves and insects can physically contaminate the edible leaf material. The two-spotted spider mite (*Tetranychus urticae*) can also infest this plant and is commonly controlled in New Zealand using mitacides or through the use of predatory mites and ladybirds.

At least two of the plant health issues identified indicate a common relationship between NZ spinach and potatoes (*Solanum tuberosum* L.) which in turn indicates some caution should be applied when both crops are likely to be grown within a crop rotation period or as neighbouring crops. Furthermore as NZ spinach is tolerant of more alkaline soils it may be a useful crop to follow winter brassicas which are generally grown in soils of pH 6.5 or higher. There is no indication that this plant is susceptible to any soil diseases at the more alkaline pH therefore it would be a useful addition to any rotation incorporating brassicas at least once in every three or four years.

Conclusion

In New Zealand, kōkihi is undervalued and primarily recognised as a home garden plant rather than a commercial vegetable. In general, kōkihi is tolerant of most pests and diseases in the New Zealand environment and requires minimal input for maintenance. It has the potential to be produced in commercial systems as it already is in many overseas countries and the nutritional and culinary value can then be exploited in its native country. The plant is susceptible to only a minor range of pests and diseases including some rust and leaf-spot diseases. The management of the plant is therefore relatively simple and would benefit from good rotation principles. Future research could target a broad range of factors including the relationship between soil conditions (pH, drainage, soil borne pathogens) and crop establishment and plant maturity. Factors affecting seed production and seed germination need to be quantified. Finally consumer preferences could be evaluated.

References

Allan, H.H. 1961. Flora of New Zealand: Volume 1 - indigenous Tracheophyta, Psilopsida, Lycopsida, Filicopsida, Gymnospermae, Dicotyledones. Government Printer, Wellington. 1085 pp.

Anon. 2008. *Tetragonia tetragonioides.* Retrieved on 28 December 2008 from http://www.zipcodezoo.com/Plants/T/Tetragonia_tetragonioides/

Cheeseman, T.F. 1925. Manual of the New Zealand flora. Government Printer, Wellington. 1163 pp.

Dingley, J.M. 1969. Records of plant diseases in New Zealand. DSIR Bulletin 192. Government Printer, Wellington. 298 pp.

Duncan, R.A. 2004. Importation of, New Zealand spinach, (*Tetragonia tetragonioides*) Palas., from Israel into the United States. USDA, Raleigh. 9 pp.

EPPO. 2011. PQR - EPPO database on quarantine pests. Retrieved on 21 October 2011 from http://www.eppo.int

Haase, P. 1990. Potential plant genetic resources of the New Zealand flora. *Economic Botany* 44:503-515.

HEAR. 2011. *Tetragonia tetragonioides*. Retrieved on 21 October 2011 from http://www.hear.org/species/tetragonia_tetragonioides/

Hedrick. U.P. 1919. Sturtevant's notes on edible plants. Report to the New York Agricultural Experiment Station for the year 1919 II. J B Lyon Company, Albany, New York State. 686 pp.

Johnson, P.N. 1976. Vegetation and flora of Womens Island, Foveaux Strait, New Zealand. *New Zealand Journal of Botany* 14: 327-331.

Knight, K.W.L. 2001. Plant parasitic nematodes associated with six subtropical crops in New Zealand. *New Zealand Journal of Crop and Horticultural Science* 29: 267-275.

McKenzie, E.H.C. 1998. Rust fungi of New Zealand - an introduction and list of recorded species. *New Zealand Journal of Botany* 36: 233-271.

McLuckie, J. and McKee, H.S. 1962. Australian and New Zealand botany. Horwitz Grahame, Sydney. 758 pp.

McNab, R.F.R. 1966. Additions to the rust fungi of New Zealand - 4. *New Zealand Journal of Botany* 4: 86-94.

Matthews, B.A. 1977. Illustrations of indigenous New Zealand plants in Curtis's Botanical Magazine. *New Zealand Journal of Botany* 15: 767-773.

Prakash, N.1967. Life history of *Tetragonia tetragonioides* (Pall.) O. Kuntze. *Australian Journal of Botany* 15: 413-424.

Roskruge, N. 2007. Hokia ki te whenua. Unpublished PhD Thesis. Massey University, Palmerston North. 263 pp.

Smith, K. 1998. Growing uncommon fruits and vegetables in Australia. New Holland Publications, French Forests, New South Wales. 164 pp.

Stephens, J.M. 2003. Spinach, New Zealand - *Tetragonia tetragonioides* (Pallas) O. Ktze., Doc. HS672. Horticulture Sciences Deparment, University of Florida. 1 p.

Sykes, W.R. 1977. Kermadec Islands flora: an annotated check list. DSIR Bulletin 219. DSIR, Wellington. 216 pp.

University of Massachusetts. 2008. New Zealand spinach. Retrieved on 9 January 2009 from http://www.umassvegetable.org/ethnic-crops/crops/new-zealand-spinach.html

Vietmeyer, N. 1991. The lost crop of the Kiwis. *New Zealand Geographic* 10: 64.

Wall, A. and Allan, H.H. 1950. The botanical names of the flora of New Zealand: their origin, history and meaning, with hints on pronunciation. Whitcombe & Tombs Ltd, Christchurch. 92 pp.

Wallace, E. 2000. VGH 2000: vegetable grower's handbook, Agro-Research Publications, Havelock North. 223 pp.

Watkins, C.B., Brown, J.M.A. and Dromgoole, F.I. 1988. Salt tolerance of the coastal plant, *Tetragonia trigyna* Banks et Sol. Ex Hook. (climbing New Zealand spinach). *New Zealand Journal of Botany* 26: 153-162.

Wilson, C., Lesch, S.M. and Grieve, C.M. 2000. Growth stage modulates salinity tolerance of New Zealand spinach (*Tetragonia tetragonioides*, Pall.) and red orach (*Atriplex hortensis* L.). *Annals of Botany* 85: 501-509.