Tackling NCDs from the ground up: Nutritious leafy vegetables to improve nutrition security on Pacific atolls

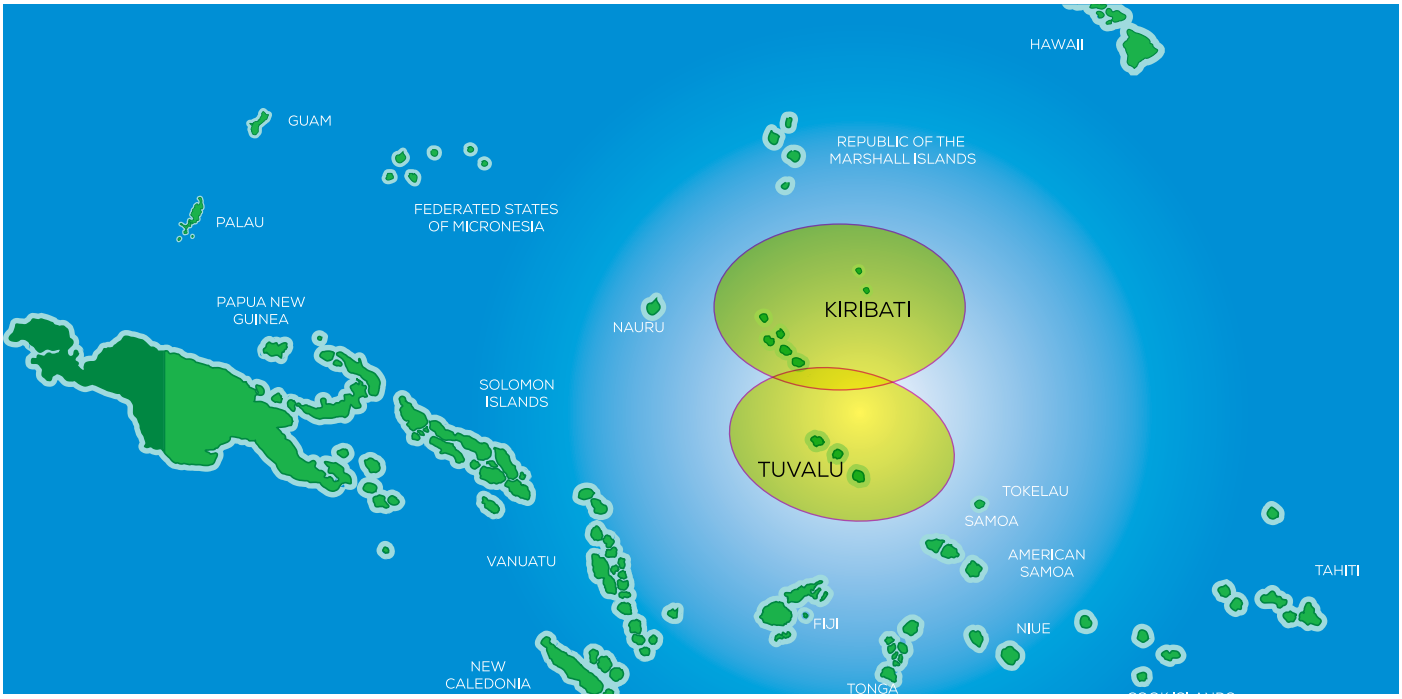
Introduction

Epidemic of non-communicable diseases (NCDs)

Since the 1940s the consumption of high-energy, low-nutrient foods, including white flour, sugar, polished rice, turkey tails and mutton rib flaps by Pacific Islanders and indigenous Australians, combined with reduced exercise, has resulted in alarming rates of obesity, heart disease, diabetes and certain cancers. Indeed, **around 70% of deaths in Pacific Island countries (PICs) are due to NCDs.** Apart from the tragic personal cost, premature death and disability undermines national economic productivity. These conditions were not present when traditional diets and lifestyles predominated. In addition, many PICs are affected by the "double burden" of NCDs and undernutrition; for example, high rates of iron deficiency anaemia in PNG, Fiji, Solomon Islands and Tuvalu.

This project, funded by the **Australian Centre for International Agricultural Research (ACIAR)** and titled *Improving soil health, agricultural productivity and food security on atolls* (ACIAR SMCN2014/089) builds on the project Feasibility study on increasing the consumption of nutritionally-rich leafy vegetables by indigenous communities in Samoa, Solomon Islands and Northern Australia (ACIAR PC/2010/063): www.aciar.gov.au/publication/fr2014-15 The project included a GxE study in which single leafy vegetable species were sampled across different sites/different soils and multiple species growing at the same site were sampled, then analysed for mineral nutrients and carotenoids, including beta-carotene (pro-vitamin A). This approach enabled partitioning of the effects of environment (mostly soil type) and genetics (plant species). The data were used to identify the most nutritious species and these are featured in a factsheet series: www.aciar.gov.au/News2013July

Can the high rates of NCDs in Pacific Island countries, and atolls in particular, be reduced while improving nutrition security and income on atolls? To address this question, this project, which commenced in 2016, aims to diversify food crop production, including nutritious leafy vegetables, on outer island atolls of Kiribati and Tuvalu. It is linked to the **International Fund for Agricultural Development (IFAD)'s *Outer Islands Food and Water Project.***



Project location: atolls of Kiribati and Tuvalu. The project is implemented by SPC, Suva, Fiji, in conjunction with The University of Tasmania and The University of Adelaide, and funded by ACIAR, Canberra, Australia

The special case of atolls

Although the project focuses on Kiribati and Tuvalu, it is also relevant to other Pacific and Indian Ocean atolls. Atoll soils are formed almost entirely from coral (calcium carbonate with some magnesium). They are coarse-textured with no clay, so water flows straight through them. Moreover, droughts are common in this part of the world. The soil is often salty, highly alkaline (high pH) and low in nutrients such as potassium, iron and anganese. Iron deficiency is usually shown by yellow young leaves and stunted growth. Furthermore, inorganic fertilisers and chemical pesticides are prohibited on the atolls as they could pollute valuable underground fresh water.

Our criteria for ***atoll suitable* leafy vegetables** are: 1) Highly nutritious, 2) Taste good, 3) Tolerant of alkalinity (high soil pH), 4) Tolerant of salt and drought, 5) Easy to grow, prepare and cook.

In a scoping study for the current project, we collected leaf, soil and compost samples in Kiribati and Tuvalu. Surprisingly, we found 11 of the 12 leafy vegetables featured in the earlier factsheets growing on South Tarawa and Funafuti, in gardens and hedges; however, they were usually used for animal feed or as ornamentals. Clearly, raising awareness is an important program component, which includes school food gardens and curriculum development, farmer field schools, village workshops and media promotion.

Improving soil health through targeted composting, along with growing and eating nutritious crops on atolls will lead to improved diet, nutrition and health. This also makes economic sense by reducing trade deficits associated with the high consumption of imported foods in countries like Kiribati and Tuvalu, where imported food comprises about 65 % of food eaten. Moreover, increased food crop diversity enhances the resilience of food systems to climate change, and thus strengthens food and nutrition security.

Giant swamp taro food garden

How better to grow these crops than with traditional Giant swamp taro pits? (*Cyrtosperma merkusii*, called *babai* in Kiribati and *pulaka* in Tuvalu). These have been historically dug by hand down to the water table. Many of these pits are now neglected but they provide a strong connection to both culture and underground water.

Babai food garden under development on Abemama Island, Kiribati in February 2017

In an adaptation of this pit system, kangkong can be grown in the water with the swamp taro. Hence the drought tolerance requirement is waived for this species. The other crops are grown on terraces forming the pit walls, and drumstick, ofenga, hedge panax and yellow beach pea are planted around the pit at ground level. Other crops, such as bananas, pawpaw, sweet potato and annual vegetables can be included. This mini food system can, once established, provide virtually complete nutrition for a family. The size can be as small as 100 square metres or as large as 0.3 hectares. In crowded places, such as Betio on South Tarawa, there is usually room to at least plant a drumstick tree or two, which would soon provide a sustainable daily supply of leaves for a family.

Why leafy vegetables?

Many different types of leafy vegetables are grown and eaten in the Pacific region. When available, local vegetables are usually inexpensive and thus affordable to most people in both urban and rural areas; despite this, they are often overlooked, being sometimes regarded as "low status foods". However, research has shown they are valuable foods, being nutritious and rich in protein, minerals, vitamins (e.g. A, B, C, K), beneficial phyto (plant) compounds and fibre. Moreover, leaves are an ideal weight loss food.

Iron is an important mineral nutrient found in leafy vegetables. Lack of iron can cause iron-deficiency anaemia, common in women, inducing fatigue and weakness, and in children, affecting growth, energy levels and learning ability. Chaya, yellow beach pea, purslane, pumpkin/choko tips and kangkong are good sources of iron.

Phytocompounds such as flavonoids, anthocyanins, polyphenols and carotenoids are beneficial to humans as antioxidants and anti-inflammatory agents in reducing the risk of diabetes, heart disease and cancers; for example, glucosinolates in drumstick leaves and anthocyanins in purple sweetpotato leaves. Certain carotenoids, notably beta- and alpha-carotene, are converted to vitamin A when eaten, especially if consumed with some oil (e.g. coconut cream). Others, notably lutein (which is often abundant in leafy vegetables) and zeaxanthin are important for eye health, including reducing the risk of cataracts.

Although this project focuses on the food/nutritional value of leafy green vegetables, traditionally in many countries they are used for specific medical applications; for example, chaya (from Mexico) protects the heart, liver and kidneys from toxin damage; drumstick (India and Pakistan) has anti-bacterial effects; bele (Papua New Guinea and Solomon Islands) is used for bone repair and treating osteoporosis, and hedge panax, drumstick, chaya and bele can stimulate lactation. Especially important, given the high NCD (particularly diabetes) rates in the Pacific and Northern Australia, are the anti-diabetes effects of chaya, drumstick, ofenga, amaranth and purslane, demonstrated in scientific studies. We believe that NCDs need to be tackled using this *food system* approach, starting with the soil.

How to eat these nutritious vegetables

It is recommended to eat around one and a half cupfuls or three handfuls (around 150 ml or grams) of leafy vegetables each day. Some green leaves can be eaten uncooked, for example kangkong, drumstick and chilli, which preserves most vitamins. Optimum cooking methods are steaming, simmering in a little water, baking or stir frying in a little oil (ideally virgin coconut oil or coconut cream) for minimal time to limit nutrient loss. The cooking water can be used for soup. **A simple method which suits all of these vegetables is: chop them into small pieces (except drumstick, in which case strip the leaflets from the wiry petioles), simmer in water for 10-15 minutes, add coconut cream and simmer for a further 10-15 minutes.** Other ingredients can be added if further flavour is desired.

The factsheets

In addition to this introductory factsheet, 12 factsheets have been produced, which feature the most *atoll suitable* nutritious leafy vegetables identified during the project. Numerous other leafy plants in the Pacific are suitable for eating and nearly as nutritious as those featured here, for example the Lettuce Tree (*Pisonia grandis;* te buka, puka vai) though some may not be as suitable for atolls that are subject to drought; for example, sweet potato, cassava and edible ferns. The Bird's Nest Fern (*Asplenium nidus*; katafa, laukatafa, laulu) is popular, especially in Tuvalu, in particular the youngest leaves cooked in coconut cream. We found it to be relatively high in potassium and boron. Leaf mineral and carotenoid (if analysed) data are presented in each factsheet in the form of a table which includes the featured leafy vegetable sampled at a particular representative site, compared with other leafy vegetables growing at the same site. English cabbage is also included, as a moderately nutritious yardstick, using average values of samples purchased at markets in the South Pacific. The final factsheet #13 discusses nutritional aspects of composting materials suitable for atolls.

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Designed by Pacific Community Land Resources Division ICKM team May 2018

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AMARANTH

Botanical name: *Amaranthus spp.* (Amaranthaceae)

Location specific common names: te mota (Kiribati), mota (Tuvalu), moca, tubua, aupa, bhaji, bayam

Plant Characteristics: Amaranth is a small to medium-sized annual bushy plant with a distinct taproot, diamond shaped leaves and feather-like seed heads. Numerous species exist, many selected and grown for grain, leaves or for their ornamental value, although some are classed as weeds. *A. tricolor* is a popular species for leaf production**.** Amaranth grows well on coralline atoll soils, especially with composting.

Uses: Young leaves of most species are edible but some produce large tender leaves and are grown specifically for leaf consumption. Leaves are best prepared lightly steamed; older leaves require longer steaming or they can be added to moist dishes like soups, curries and stews. Uncooked amaranth leaves should not be consumed as the oxalate content reduces the bioavailability of iron, zinc, calcium and magnesium; cooking reduces the oxalate level. Tender stem tips are better peeled before cooking.

Medicinal: Amaranth leaves are used in many countries to treat inflammation, fever, digestive tract disorders (including diarrhoea, dysentery, ulcers), and reduce risk of heart disease and diabetes by lowering high blood pressure, high low-density-lipoprotein cholesterol and blood sugar level. Scientific studies provide evidence to support these effects.

Availability: Amaranth can be grown year-round in most tropical and subtropical locations. It is reported to be the most popular leafy vegetable in Fiji, but is not yet marketed in Kiribati or Tuvalu.

Propagation methods: New plants are produced from seeds, which are very small; young seedlings transplant readily.

How to grow: Amaranth is well suited to growing in large pots or garden beds with a well-drained loam and compost mix. It will grow in full sun, but afternoon shade encourages good leaf production. Soils of poorer fertility and insufficient water produce slower growing, smaller leaved plants with thinner stems, which flower earlier.

Threats: This plant is relatively pest/disease resistant; however, leaf eating insects such as grasshoppers are occasional pests and may become a problem.

Harvesting: Plant growth is promoted by regular harvesting. The tips, usually back to the 5th newest full leaf and fresh looking older leaves can be picked and loosely packed in moist paper. Harvesting in the cooler hours of the day prevents drying/wilting. Once a tip has been harvested the plant will continue to grow and produce one or more new tips suitable for picking in a few weeks.

Post harvest and storage: Leaves should be washed carefully with water of drinking quality or clean seawater. They can be bundled with their stems trimmed and stood upright in a small amount of clean fresh water. If covered with a clean plastic bag and kept cool, they should store for a day or two. If placed in an airtight container in a refrigerator they can last for up to a week. Leaves are firm and can be stored frozen.

Project findings/Nutritional value: Samples were collected in Kiribati and Samoa (see table below). Amaranth is a nutritious all-rounder, being a good source of protein, carotenoids and most minerals, particularly zinc, calcium and magnesium. About two handfuls (100 grams) per person for a meal serving will provide useful nutrition.

Protein: This is important in forming muscle, cell membranes, enzymes, blood components, antibodies, DNA and RNA. The mean nitrogen analyses of our samples indicated a good protein level of around 19%.

Carotenoids: Lutein is important for eye health (e.g. reducing risk of cataracts), and beta-carotene (pro-vitamin A) is important for vision, immunity and bone health.

Zinc: Important for immunity, growth, carbohydrate metabolism, and DNA and protein formation. Humans have around 600 different Zn-containing enzymes/proteins.

Magnesium: This mineral is important in bone formation, energy production, and nerve and muscle function.

Calcium: The most important mineral for the growth and maintenance of bones and teeth. Calcium is also important for cellular physiology.

This table compares selected mineral nutrients and carotenoids in leaves of amaranth and sweetpotato grown together at Lotofaga, Upolu, Samoa in 2012 and English cabbage (average of samples bought from Honiara market, Solomon Islands and Nukualofa market, Tonga in 2012) (concentration in mg/kg dry weight, except N: % dry weight). The amaranth sample collected on Tabiteuea North atoll, Kiribati was higher in Zn and Mn and lower in N, P & K than the Samoa sample.

	Mn	Zn	Ca	Mg	K	P	S	N %	lutein	alpha carotene	beta carotene
Amaranth	58	**64**	**15500**	**18800**	**45000**	6400	4400	**5.3**	**462**	8	**350**
Sweetpotato	75	23	5500	4600	15900	3600	3200	4.6	**457**	10	**317**
Cabbage	23	20	5700	1450	29000	3750	3750	2.8	5	0	2

Mn: manganese; Zn: zinc; Ca: calcium; Mg: magnesium; K: potassium; P: phosphorus; S: sulphur; N: nitrogen
Analyses conducted by Waite Analytical Services and the Mares Laboratory, University of Adelaide, South Australia

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Compiled by G. Lyons, G. Dean, R. Goebel, M. Taylor, R. Kiata. Layout by S.Tukidia

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CHAYA

Botanical name: *Cnidoscolus aconitifolius* (Euphorbiaceae)
Location specific common names: te tiaia (Kiribati), tiaia (Tuvalu), tree spinach

Plant Characteristics: Chaya is a large, fast growing perennial shrub originating from the Yucatan Peninsula, Mexico. It is a Euphorbia with characteristic milky sap. It can grow to 3-5 metres in height, and is tolerant of drought, salt and alkaline soil. This, along with its lack of appeal to pathogens and insect pests, makes it an ideal leafy vegetable for atolls.

Chaya was introduced to Kiribati and Tuvalu under the Pacific Regional Agriculture Program (PRAP) Stage 1 in 1993. Its adaptability and good flavour (similar to spinach) made it popular and widely grown in gardens. However, misinformation concerning its supposed toxicity resulted in a widespread belief that it caused hepatitis, so it was relegated to pig feed or considered a weed. Indeed, the opposite is true: one of chaya's health/medical benefits is its ability to protect the liver from toxins (see below). Like cassava leaves, chaya leaves contain small amounts of cyanogenic glycosides (though at lower levels than usually found in cassava). Steaming/boiling for 3 minutes will remove these. They are volatilised (disappear into the air), thus the cooking water, as with all of the leafy vegetables in the factsheets, can be used for soup.

Uses: Chaya is cultivated extensively in Mexico for use as a food and medicine. Leaves are best prepared steamed or boiled in a small amount of water, then coconut cream added and cooking continued for 10-15 minutes more.

Medicinal: Chaya is traditionally used in Mexico and Central America to prevent and treat such diverse conditions as inflammation, diabetes (there is strong evidence for this benefit), obesity, heart disease (it lowers LDL-cholesterol and high blood pressure), fever, kidney stones, varicose veins, gastro-intestinal disorders, respiratory infections and eye problems. It is also considered to protect the heart, liver and kidneys from toxins, especially under protein-energy malnutrition. Moreover, like drumstick, hedge panax and bele, it stimulates lactation.

Here is a recipe for tasty leaf soup: 3 handfuls of chaya (or hedge panax, ofenga, drumstick, amaranth, kangkong, pumpkin, chili, bele) leaves, 1 cup thinly sliced fish/meat, ½ teaspoon cassava flour, 1 teaspoon soy sauce, ½ teaspoon sugar, 1 tablespoon coconut oil (or 3 tablespoons coconut cream), 1 onion (or several spring onions or a chilli), chopped, 2 teaspoons sliced ginger, 6 cups water, salt, pepper.

Availability: Despite the misinformation about chaya referred to above, plants can still be found in Kiribati and Tuvalu, growing healthily.

Propagation methods: Healthy chaya plants provide suitable sources of planting material. Although chaya can often be seen flowering, it rarely produces seeds, thus actively growing stems (25-50cm long) are the recommended planting material.

How to grow: Ensure the cuttings are grown in composted soil and water well for the first 3 months until established, or longer under drought conditions. Then this plant usually grows well even under tough conditions. Unless being used for agroforestry, the bushes will need pruning to enable easy harvest of leaves.

Threats: Chaya is very tolerant of diseases and pests, even more so than amaranth (Factsheet 2) and much less attractive to insects than bele (Factsheet 10).

Harvesting: Once established, leaves can be harvested regularly. As with most of the featured vegetables, ensure that the plant retains at least two-thirds of its foliage at any time, otherwise it may not recover from heavy leaf removal, especially during a drought.

Post harvest and storage: Leaves should be washed carefully with water of drinking quality or clean seawater. Like amaranth and bele, they can be bundled with their stems trimmed and stood upright in a small amount of clean fresh water. If covered with a clean plastic bag and kept cool, they should store for a day or two. If placed in an airtight container in a refrigerator they can last for up to a week. Leaves are firm and can be stored frozen.

Project findings/nutritional value: Samples were collected in Kiribati (see table below) and Tuvalu. Like amaranth, chaya is a nutritious all-rounder, but especially notable for protein and iron. It has even been described as a "Mayan green superfood". In this study, we analysed a range of minerals, including nitrogen. About two handfuls (100 grams) per person for a meal serving will provide very useful nutrition.

One chaya sample collected at Eita, Tabiteuea North atoll, Kiribati was technically deficient in copper manganese and potassium but appeared healthy, with no deficiency symptoms. This suggests that chaya is efficient for these nutrients, which would partly explain its excellent growth on high pH atoll soils.

Chaya is strong in protein, iron and carotenoids:

Protein: This is important in forming muscle, cell membranes, enzymes, blood components, antibodies, DNA and RNA. The mean nitrogen analyses of our chaya samples indicated an excellent protein level of around 23 %, similar to that of most legumes, which are nitrogen-fixers.

Iron: Important for healthy blood and energy.

Carotenoids: Although we did not measure carotenoids in this project, other studies have found chaya to be a good source of vitamins A, B and C. Serrano *et al* (2005) found high levels of lutein (1,922 mg/kg) and b-carotene (515 mg/kg) in chaya leaves. Lutein is important for eye health (e.g. reducing risk of cataracts) and b-carotene (pro-vitamin A) is important for vision, immunity and bone health.

This table compares selected mineral nutrients in leaves of chaya, cassava and noni grown together at Betio, South Tarawa, Kiribati, and English cabbage (average of samples bought from Honiara market, Solomon Islands and Nukualofa market, Tonga in 2012) (concentration in mg/kg dry weight, except N: % dry weight).

	Fe	Mn	Zn	Ca	Mg	K	P	S	N %
Chaya	**97**	12	32	**16000**	5600	18100	3600	3500	**5.2**
Cassava	**98**	25	**89**	12300	5100	**16100**	4100	3500	**5.4**
Noni	**95**	9	24	11900	3700	11100	1470	2200	3.0
Cabbage	40	23	20	5700	1450	**29000**	3750	3750	2.8

Fe: iron; Mn: manganese; Zn: zinc; Ca: calcium; Mg: magnesium; K: potassium; P: phosphorus; S: sulphur; N: nitrogen
Analyses conducted by Waite Analytical Services and the Mares Laboratory, University of Adelaide, South Australia

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DRUMSTICK TREE

Botanical name: *Moringa oleifera* (Moringaceae)

Location specific common names: te turam (Kiribati), saitani (Tuvalu), moringa, saijan, horseradish tree, mulangay

Plant Characteristics: This plant grows into a medium sized tree, 4 to 6 metres tall. It can be kept to a useful size by regular pruning, and can be trained to grow as a hedge. The name *drumstick* comes from the distinctive long tapered seedpods that hang from the branches.

Uses: Leaves are best prepared soon after picking. The leaflets can be eaten in salads after washing, although the somewhat strong flavour may deter some people. This is not an issue when the leaves are incorporated with soups, curries or stews. As with all of the nutritious leafy vegetables featured in the factsheets, it is recommended to include coconut cream or coconut oil in cooking: not only does this enhance the flavour, but it also increases the bioavailability of fat-soluble carotenoids, and increases the bioconversion of b-carotene (pro-vitamin A) to vitamin A. If no coconut cream/oil are available, palm oil and peanut oil are suitable.

Here is a simple recipe which provides a very tasty and nutritious dish: rinse 6 handfuls of leaves (just fully developed). Strip the leaflets from the wiry stalks, (these do not soften with cooking), and add to 1 litre of fish soup base, flavoured with 2 finely shredded lime leaves or lemon grass, add salt, pepper and chilli to taste. Bring to simmer for 1 minute. This will serve 4 people.

The drumstick tree is also used for livestock fodder, living fences, fertilizer/green manure and for purifying water (using seeds).

Medicinal: Drumstick leaves are probably unequalled among plants for their nutritional and medicinal properties. Traditionally in India, Pakistan and Sri Lanka drumstick has been used as an anti-inflammatory, anti-bacterial, anti-viral and anti-cancer agent. Strong evidence exists for its anti-diabetes and anti-heart disease activity, through mechanisms that decrease blood sugar, harmful blood fats and high blood pressure. This is especially relevant to Pacific Island countries and Northern Australia, with their high rates of diabetes and heart disease. Drumstick can also stimulate lactation.

Availability: Drumstick trees are common in Fiji, but can be scarce in other Pacific islands and in northern Australia. Seed was imported to Kiribati from Fiji in 1992/93. ALD nurseries in Kiribati are usually good sources of planting material, and seed is plentiful at ALD's Tanaea, South Tarawa headquarters.

Propagation methods: Plants can be produced from cuttings or seed; seed-derived plants are usually slower to establish but develop a stronger root system. Cuttings of mature wood, 200 to 600 mm long, planted with at least one-third of the cutting in the soil, are most suitable for propagation.

How to grow: Drumstick trees are not difficult to grow. Once established, the tree is drought, salt and wind tolerant, can survive on shallow soil of poor fertility and will grow well in full sun. Grown plants need to be pruned to facilitate regular leaf harvesting. Indeed, established drumstick trees/bushes can be defoliated virtually right back to the stump/roots and will readily bounce back when provided with some moisture. If growing conditions are poor, growth will be slower, and leaves smaller with a stronger flavour. For the first two years mulching is recommended, keeping the soil around the tree moist and free of grass and other weeds.

Threats: Pests and diseases are not usually a problem; however root rot can occur if the tree is grown in waterlogged soils.

Harvesting: Due to its vigour, drumstick can be harvested quite heavily and will recover rapidly. This is best done in the cooler hours of the day to prevent wilting.

Post harvest and storage: Full leaves (leaflets plus wiry stalks) should be washed carefully with water of drinking quality or clean seawater. Leaves can be frozen for later use. If bundle wrapped in moist paper and kept in a cool location they should store for a day. Leaves can last for up to a week, if placed in an airtight container in a cool room or refrigerator. If the leaves dry they will drop their leaflets and lose some food value.

Project findings/nutritional value: Samples were collected from Kiribati, Tuvalu, Torres Strait Islands, Solomon Islands and Samoa. About two handfuls (100 grams) per person for a meal serving will provide useful nutrition. The leaves are renowned for their high levels of minerals, vitamins (A, B, C), protein, carotenoids and other phytochemicals, including the anticancer compounds glucosinolates and isothiocyanates.

Protein: This is important in forming muscle, cell membranes, enzymes, blood components, antibodies, DNA and RNA. The mean nitrogen analyses of our drumstick samples indicated an excellent protein level of around 22 %, similar to that of most legumes, which are nitrogen-fixers.

Carotenoids: A Solomons drumstick tree sample was the highest of all of our leaf samples for beta-carotene (pro-vitamin A), and was also high in lutein, which is important for eye health.

Iron: Important for healthy blood and energy.

Sulphur: This mineral is needed for production of the hormone insulin, which controls blood sugar level. Sulphur is also needed for the protein keratin, important for bone, cartilage and tendons. Drumstick tree leaves are usually 3-4 times higher in sulphur than leaves of other plants growing on the same soil.

Selenium: Important in antioxidant enzymes, for thyroid and brain function and for its antiviral and anticancer effects. Drumstick tree leaves are usually 10-12 times higher in selenium than those of other plants growing nearby.

This table compares selected mineral nutrients and carotenoids in leaves of drumstick tree and bele (aibika) grown together at Burns Creek, Honiara, Solomon Islands in 2012 and English cabbage (average of samples bought from Honiara market, Solomon Islands and Nukualofa market, Tonga in 2012) (concentration in mg/kg dry weight, except N: % dry weight). Bele data: average of 3 varieties.

	Fe	Cu	Zn	Ca	Mg	S	N %	Se	lutein	alpha carotene	beta carotene
Drumstick	**82**	7	31	**20000**	3700	**12300**	**5.1**	**2.0**	**773**	0	**427**
Bele	**73**	8	**44**	**23600**	**7100**	4500	**4.9**	0.17	**1006**	31	**358**
Cabbage	40	2	20	5700	1450	3750	2.8	na	5	0	2

Fe: iron; Cu: copper; Zn: zinc; Ca: calcium; Mg: magnesium; S: sulphur; N: nitrogen; Se: selenium na: not analysed

Analyses conducted by Waite Analytical Services and the Mares Laboratory, University of Adelaide, South Australia

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Compiled by G Lyons, G Dean, R Goebel, M Taylor, R Kiata. Layout by S Tukidia.

HEDGE PANAX

Botanical name: *Polyscias scutellaria* (Araliaceae)

Location specific common names: te toara, te baa mangkongko (Kiribati), lautagitagi (Tuvalu), danidani (Fiji), tagitaki (Samoa), ete (Solomon Islands), dinner plate aralia, cup-leaved papua, bebero, geke, paa, bebenu, kobikobi, momotu

Plant Characteristics: Originating on the Malayan Peninsula, hedge panax is a tall shrub, growing 3-6m high and 2-3m wide, often planted as a hedge. Leaves of specific members of the *Polyscias* genus vary in shape from large, round and shiny to narrow and fernlike.

Uses: The young leaves of hedge panax have the best taste and can be eaten fresh, but mature leaves are usually cooked in stews and soups, ideally with coconut cream to increase carotenoid availability and conversion to vitamin A.
Medicinal: Hedge panax has been traditionally used in Malaysia, Melanesia and elsewhere in the tropics to increase milk production in nursing women. It also has anti-inflammatory effects, and is used to enhance the healing of ulcers and wounds. In the Philippines it is used as a diuretic, and in the Western Pacific its macerated bark is used for the treatment of ciguatera poisoning. Ciguatera is food poisoning caused by a toxin that can accumulate in large reef fish. It can cause nausea, pain, heart and neurological (nerve/brain) symptoms.

Availability: This plant and its related species grow all year in the tropics. It is widespread in the Pacific, mostly in coastal areas, especially on high pH coralline soils. It is common throughout Tuvalu but unevenly distributed in Kiribati, being quite common on Butaritari and South Tarawa (for example, at Teaoraereke and Bikenibeu), but scarce elsewhere.

Propagation methods: Hedge panax is usually grown from stem cuttings, ideally 2-2.5cm in diameter and around 40cm long, but can also be grown from seed. The area around the cuttings should be mulched and watered for the first 3 months to help establishment.

How to grow: Hedge panax prefers high pH soils, i.e. 7.6-8.6, and will grow well on coralline soils with low available iron, copper, manganese, potassium and phosphorus, while other crops such as cassava grow poorly and exhibit pale/yellow leaves (chlorosis) on these soils. This indicates that hedge panax is very efficient for these minerals; in other words, it is able to carry out photosynthesis and other physiological processes satisfactorily, using lower levels of these nutrients than most other plants.

Threats: Pink wax scale (*Ceroplastes rubens*) and passion vine mealybug (*Planococcus pacificus*) can cause problems.

Harvesting: Young and older leaves can be harvested on a daily basis. Leaves for food can be collected at the same time as a hedge is trimmed, which helps to keep the hedge tidy.

Post harvest and storage: *Polyscias* leaves, like the other recommended leafy vegetables, should be washed with clean water and stored in a cool, shady place. Ideally, leaves should be eaten within a day of picking, but the large-leafed forms, including *P. scutellaria*, which are quite fibrous, can remain fresh for up to 3 days.

Project findings/nutritional value: Samples were collected in Kiribati, Tuvalu and Solomon Islands (Guadalcanal and Santa Ysabel). Hedge panax was consistently among the best of the leaf samples for accumulation of zinc, on average second to leaves of cassava, a renowned zinc accumulator, and was also high in calcium compared to most leafy vegetables. About two handfuls (100 grams) per person for a meal serving will provide useful nutrition. It is worth noting that while cassava is outstanding at extracting zinc from high-pH soils, it is much less successful at extracting iron from these soils and is hence susceptible to iron deficiency on calcareous soils above about pH (in water) 8.0.

Hedge panax is strong in:

Zinc: Important for immunity, growth, carbohydrate metabolism, and DNA and protein formation. Humans have around 600 different Zn-containing enzymes/proteins.

Calcium: The most important mineral for the growth and maintenance of bones and teeth. Calcium is also important for cellular physiology.

This table compares selected mineral nutrients and carotenoids in leaves of hedge panax (average of three varieties), cassava (average of two varieties) and *Ficus copiosa* (sandpaper cabbage) grown together on high pH soil on Ta-wa'ahi Island, Marau, Guadalcanal, Solomon Islands in 2012 and English cabbage (average of samples bought from Honiara market, Solomon Islands and Nukualofa market, Tonga in 2012) (concentration in mg/kg dry weight, except N: % dry weight).

	Fe	B	Cu	Zn	Ca	Mg	K	N %	lutein	alpha carotene	beta carotene
Hedge panax	31	45	7	**92**	**27000**	6800	18000	2.6	250	30	74
Cassava	35	**85**	7	**67**	**20100**	6200	11400	3.6	**310**	1	175
Ficus	28	44	6	28	**23500**	4100	20000	2.3	**290**	24	72
Cabbage	40	12	2	20	5700	1450	**29000**	2.8	5	0	2

Fe: iron; B: boron; Cu: copper; Zn: zinc; Ca: calcium; Mg: magnesium; K: potassium; N: nitrogen
Analyses conducted by Waite Analytical Services and the Mares Laboratory, University of Adelaide, South Australia

This fact sheet is one of a series produced for the Australian Centre for International Agricultural Research (ACIAR) funded activity "Improving soil health, agricultural productivity and food security on atolls: SMCN2014/089". It is based on fact sheet no.4 in the series produced during the project ACIAR PC/2010/063

Compiled by G Lyons, G Dean, R Goebel, M Taylor, R Kiata. Layout by S Tukidia.

OFENGA

Botanical name: *Pseuderanthemum whartonianum; P. carruthersii* (Acanthaceae)

Location specific common names: Carruthers' falseface, false eranthemum, *P. carruthersii var. carruthersii* (green leaf): te iamaii (Kiribati); ofenga (Tuvalu, Solomons), pure, burape; *P. carruthersii var. atropurpureum (*red/purple leaf): te iaro (Kiribati) (pictured below, left); *P. carruthersii* var. *reticulatum* (green lower leaves and yellowish upper leaves with obvious veins, pictured below, right).

Plant Characteristics: Ofenga, which originates from North Vietnam, is a tall shrub, growing up to 6m high. The leaves have prominent veins and are oval-shaped, narrowing to a point at both ends. Both species are similarly nutritious. The flowers are purple and white.

Uses: Young leaves can be eaten fresh, but any leaves can be cooked in soups, stews and curries, ideally with coconut cream to increase carotenoid availability and conversion to vitamin A. Some people consider this plant to have the best flavour of all of the recommended leafy vegetables. **Medicinal:** Ofenga is used, particularly in Vietnam and Thailand, to treat high blood pressure, diarrhoea, wounds, arthritis, tumours and diabetes. The study of Padee *et al (2010)* see Factsheet 1) supports the use of *P. palatiferum* (a close relative of *P. whartonianum* and *P. carruthersii*) to combat diabetes.

Availability: Ofenga grows all year in the tropics and is widespread in the Pacific, especially in Solomon Islands (particularly Malaita) and Vanuatu, near the coast in gardens and as hedges, and wild in rainforest. Both species are common on South Tarawa and Funafuti and less so on outer islands. Like chaya and drumstick, it is often found in ALD nurseries in Kiribati.

Propagation methods: Like hedge panax, ofenga is usually grown from stem cuttings around 2cm thick and 40cm long, but can also be grown from seed. The area around the cuttings should be mulched and watered for the first 3 months to help establishment.

How to grow: Ofenga is not as iron efficient as hedge panax but still grows well on atolls, especially with adequate composting.

Threats: Pink wax scale (*Ceroplastes rubens*) and passion vine mealybug (*Planococcus pacificus*) can affect the quality of ofenga leaves.

Harvesting: Young and older leaves can be harvested on a daily basis. Leaves for food can be collected at the same time as a hedge is trimmed, which helps to keep the hedge tidy.

Post harvest and storage: As for most leaves, ofenga, should be washed with clean water and stored in a cool, shady place. Ideally, leaves should be eaten within a day of picking, but can be frozen for later use.

Project findings/nutritional value: : Samples were collected in Kiribati, Tuvalu and Solomon Islands. Ofenga is an outstanding accumulator of magnesium, second only to purslane in our samples, and is also usually high in calcium and carotenoids, especially lutein (Solomon Islands samples analysed). About two handfuls (100 grams) per person for a meal serving will provide useful nutrition.

Magnesium: This mineral is important in bone formation, energy production, and nerve and muscle function. Furthermore, it has anti-inflammatory effects, and magnesium deficiency is a risk factor for obesity, metabolic syndrome and diabetes.

Calcium: The most important mineral for the growth and maintenance of bones and teeth. Calcium is also important for cellular physiology.

This table compares selected mineral nutrients in leaves of ofenga (*P. whartonianum*), drumstick and taro grown together at ALD Tanaea, South Tarawa, Kiribati in 2014 and English cabbage (average of samples bought from Honiara market, Solomon Islands and Nukualofa market, Tonga in 2012) (concentration in mg/kg dry weight, except N: % dry weight).

	Fe	Mn	B	Cu	Zn	Ca	Mg	K	S	N %
Ofenga	26	24	44	7	33	**22000**	**27000**	19600	3100	2.1
Drumstick	**65**	20	34	5	32	15800	7400	12200	**11600**	**5.4**
Taro	34	35	28	**12**	29	**33000**	6300	**29000**	2300	3.8
Cabbage	40	23	12	2	20	5700	1450	**29000**	3750	2.8

Fe: iron; Mn: manganese; B: boron; Cu: copper; Zn: zinc; Ca: calcium; Mg: magnesium; K: potassium; S: sulphur; N: nitrogen
Analyses conducted by Waite Analytical Services, University of Adelaide, South Australia

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YELLOW BEACH PEA

Botanical name: *Vigna marina* (Fabaceae)

Location specific common names: te kitoko, te biin, te ruku (Kiribati), saketa sama (Tuvalu), drautolu (Fiji), dune bean, beach cowpea, beach pea, notched cowpea, nanea. There is some confusion with another common beach-growing vine, *Ipomoea pes-caprae* (beach morning glory, a sweet potato relative with long tendrils, large shiny leaves and purple flowers), which is usually called *te ruku*.

Plant Characteristics: The origin of this creeping legume is unknown, but it is now found on tropical shorelines around the world. Its distribution has been aided by the resistance of its seeds to degradation by seawater. It has trifoliate leaves and yellow flowers which distinguishes this species from other vines. It nodulates readily: this refers to the root nodules that contain rhizobia, bacteria able to fix atmospheric nitrogen, which is then available for plant nutrition, mainly to build proteins/enzymes. This is valuable not only for *Vigna* itself but also for increasing available nitrogen in the soil for other crops grown afterwards.

Uses: Yellow beach pea leaves are more fibrous (and thus chewier) than the leaves of the other recommended nutritious leafy vegetables, thus it is best to use young leaves, which can be cooked in soups, stews and curries, ideally with coconut cream to increase carotenoid availability and conversion to vitamin A. The green pods are particularly nutritious and can be steamed or cooked in coconut cream. Foliage of *Vigna* is also useful for livestock feed. The relatively high nitrogen, iron and zinc levels in the leaves make it a valuable component of "green manure" and compost, and when grown as a "cover crop" it can suppress weeds. Other leguminous cover crops including *Mucuna, Centrosema* and *Pueraria* are not well adapted to the salty, alkaline atoll soils. **Medicinal:** In some South East Asian and Pacific countries (e.g. Hawaii) yellow beach pea is used to help heal wounds, boils and ulcers; softened leaves/stalks are applied directly to the affected area.

Availability: Yellow beach pea is salt tolerant and common on most atolls of Kiribati and Tuvalu.

Propagation methods: It can be propagated by cuttings or seed, but the best way to establish it quickly is to dig up plants and transport them with root nodules intact to the new location. This ensures that the nitrogen-fixing rhizobia accompany the plant and get it off to a good start. Legume seeds are often "hard" and require nicking with a knife or abrasion (e.g. with sandpaper), then soaking for 24 hours to facilitate germination.

How to grow: Ensure adequate water is provided until the plants are established. They are then quite drought tolerant and grow well in both sun and shade.

Threats: Fungi, including *Cercospora canescens* and *Colletrotrichum* species, and legume-eating caterpillars such as *Euchrysops cnejus* and *Lampides boeticus* can cause problems. It is sensitive to frost, although this is not an issue at low altitudes in the tropics.

Harvesting: As noted above, it is advisable to use young leaves (for example the five newest fully formed leaves) for eating, due to *Vigna marina*'s fibre content. The green pods are also highly recommended.

Post harvest and storage: The leaves should be washed with clean water and stored in a cool, shady place, and ideally eaten within a day of picking.

Project findings/nutritional value: Samples were collected in Kiribati and Tuvalu and were notably high in iron, zinc and protein. Although the manganese and copper levels in the *Vigna* sample featured in the table are higher than those in the other species, their levels in most of the other 6 samples collected from other locations were not noticeably higher than for other species growing on the same soil. About two handfuls (100 grams) per person for a meal serving will provide useful nutrition. Yellow beach pea is strong in:

Iron: Important for healthy blood and energy.

Zinc: Important for immunity, growth, carbohydrate metabolism, and DNA and protein formation. Humans have around 600 different Zn-containing enzymes/proteins.

Protein: This is important in forming muscle, cell membranes, enzymes, blood components, antibodies, DNA and RNA.

This table compares selected mineral nutrients in leaves of yellow beach pea, taro and *Gliricidia sepium* (a legume tree) grown together at ALD Central Nursery, Bikenibeu, South Tarawa, Kiribati in 2014 and English cabbage (average of samples bought from Honiara market, Solomon Islands and Nukualofa market, Tonga in 2012) (concentration in mg/kg dry weight, except N: % dry weight).

	Fe	Mn	Cu	Zn	Ca	Mg	K	S	N %
Yellow beach pea	**88**	**59**	**10**	**49**	13800	4200	18400	2700	**4.5**
Taro	**84**	21	2	21	11800	2300	**41000**	**4900**	**4.3**
Gliricidia	50	26	2	10	**30000**	**8200**	19400	2800	3.5
Cabbage	40	23	2	20	5700	1450	**29000**	3750	2.8

Fe: iron; Mn: manganese; Cu: copper; Zn: zinc; Ca: calcium; Mg: magnesium; K: potassium; S: sulphur; N: nitrogen
Analyses conducted by Waite Analytical Services, University of Adelaide, South Australia

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KANGKONG

Botanical name: *Ipomoea aquatica, Ipomoea reptans* (Convolvulaceae)

Location specific common names: te kangkong (Kiribati), kangkong (Tuvalu), water spinach, swamp cabbage, aquatic sweet potato.

Plant Characteristics: Under reasonable growing conditions kangkong is a fast growing, vine-like plant that spreads along the ground or water surface, and is reluctant to climb. It is a close relative to sweetpotato but is grown for its succulent growing tips rather than for roots or tubers.

There are two recognized types: the upland type, *Ipomoea reptans,* more common throughout the Pacific and adapted to moist soils and lowland or aquatic kangkong *(Ipomoea aquatica)* which is adapted to flooded conditions.

Uses: Kangkong is best prepared fresh/uncooked. After thorough washing, short succulent tips can be eaten in salads or liquidised for adding to a drink. Slightly older leaves are best cooked by steaming, boiling, frying or baking. Stems, cut into sections, can be used in a stir fry. **Medicinal:** Kangkong is renowned, not only for protecting the liver from toxins, including lead, cadmium, arsenic and carbon tetrachloride, but also for its anti-diabetes effects.

Propagation methods: New plants can be produced from cuttings or seed. Plants grown from seed are usually slower to establish and the quality is less reliable compared with plants derived from cuttings. The seeds should be soaked one day before sowing. Cuttings from 20 to 60 cm long, preferably taken a day or two after harvesting the tip, are the most suitable for propagation. Care with watering is needed until the cuttings are well established. Cuttings can be stored or transported for a few days provided they are kept in the shade, and in a little water, which must be changed often to reduce the possibility of stem rot.

How to grow: Kangkong is not difficult to grow providing the soil is rich in organic matter and water is readily available. It can grow in full sun, preferably with some shade in the afternoon. The main roots require soil to grow but the plant, which has hollow stems, will easily spread over water. Soils of poorer fertility and insufficient water will produce slower growing plants with thinner stems and smaller leaves with a stronger, bitter flavour. Cuttings of three or more nodes should be planted with at least one node under the soil surface. The area around the plant should be kept moist and free of grass and other weeds.

Threats: Pests and diseases do not usually cause problems. Leaf eating insects such as grasshoppers and some caterpillars are occasional pests that may become a problem in drier weather. Leaf miner and mealybug can cause reduced growth and malformed leaves. Healthy planting material and good growing conditions can help reduce the occurrence and impact of these pests.

Photos: wikipedimedia

Harvesting: Depending on the amount of kangkong being grown and the growing conditions, harvesting can be carried out daily. The tips, usually back to the 3rd newest full leaf, should be neatly picked or cut with a sharp knife. The cut tips can be stood upright in a bucket or container with some clean water. Tips should be harvested in the cooler hours of the day to prevent wilting. Where a tip has been harvested that runner should produce one or more new tips suitable for harvesting in a few days.

Post harvest and storage: Tips should be washed carefully with water of drinking quality or clean seawater. They can be bundled with their stems trimmed and stood upright in a small amount of clean fresh water. They should store for a day or two if covered with a clean plastic bag and kept in a cool location. If placed in an airtight container in a cool room or refrigerator, they can last for up to a week.

Project findings/nutritional value: Samples of kangkong for analysis were collected from Kiribati, northern Queensland, Tonga and Samoa. About three handfuls of fresh vegetable per person for a meal serving will provide useful nutrition.

Kangkong is strong in:

Iron: Important for healthy blood and energy. Iron was the standout mineral in the Kiribati kangkong samples, averaging 68 mg/kg.

Protein: This is important in forming muscle, cell membranes, enzymes, blood components (antibodies, DNA and RNA. The nitrogen analysis here indicates a protein content of around 19%.

This table compares selected mineral nutrients and carotenoids in leaves of kangkong and sweetpotato grown near each other at Lotofaga, Upolu, Samoa in 2012 and English cabbage (average of samples bought from Honiara market, Solomon Islands and Nukualofa market, Tonga in 2012) (concentration in mg/kg dry weight, except N: % dry weight).

	Fe	B	Cu	Zn	Ca	Mg	K	N %	lutein	alpha carotene	beta carotene
Kangkong	**75**	**93**	16	17	5500	3500	2900	**4.3**	**373**	0	226
Sweet potato	**69**	53	15	27	5500	4800	2800	3.6	**336**	6	225
Cabbage	40	12	2	20	5700	1450	**29000**	2.8	5	0	2

Fe: iron; B: boron; Cu: copper; Zn: zinc; Ca: calcium; Mg: magnesium; K: potassium; N: nitrogen
Analyses conducted by Waite Analytical Services and the Mares Laboratory, University of Adelaide, South Australia

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PUMPKIN & CHOKO

Botanical name: Pumpkin *Cucurbita spp.* (Cucurbitaceae)
Choko *Sechium edule* (Cucurbitaceae)

Location specific common names for pumpkin: te baukin (Kiribati), panikeni (Tuvalu), squash, gramma (the types used to make soup, e.g. trombone, spherical, butternut)

Location specific common names for choko: chayote, vegetable pear, cho-cho, pipinola, christophine

Plant Characteristics: There are numerous pumpkin types. The true pumpkin, *Cucurbita moschata,* is best for most tropical conditions and provides tender and sweet tips. Under favourable conditions pumpkin and choko are fast growing vine-like plants that spread along the ground and are able to climb. Choko vines need trellis support.

Uses: In addition to eating the fruit, tender growing tips of pumpkin and choko can be used fresh in salads or lightly steamed. Older leaves are best cooked by steaming, boiling, frying or baking. **Medicinal:** *Cucurbita* leaves and choko fruit have been used traditionally, especially in West Africa, to combat anaemia, fever, pathogenic bacteria and eye disorders. They have demonstrated anti-inflammatory, anti-diabetes, anti-hypertensive (can reduce high blood pressure) and anti-dyslipidaemic (can reduce harmful blood fats) effects.

Availability: The gramma types are often grown year round and are common in Kiribati and Tuvalu. Once established, choko vines can produce all year if well watered and growing vigorously.

Propagation methods: Pumpkin plants can be grown from seed which has been purchased as packaged seed, self-saved or taken from shop fruit. Choko is grown from sprouted fruit planted in the soil with the sprout above the surface. The sprouted fruit should be protected from sun and weeds.

How to grow: Pumpkins and choko are not difficult to grow providing the soil is rich in organic matter and water is readily available. They grow satisfactorily in Kiribati and Tuvalu on well composted, well watered soil. They can be grown all year in most tropical locations, including those with full sun. Soils of poorer fertility and insufficient water will produce plants with thinner stems, smaller, slower-growing leaves with a stronger, bitter flavor. The area around the plants should be kept moist and free of grass and other weeds.


Pumpkin


Choko


Choko

Threats: Some pests and diseases can be limiting factors for pumpkins and chokos. Fungal leaf diseases like downy and powdery mildew along with root nematodes can limit plant growth. Providing good growing conditions, wide plant spacing and crop rotation can reduce the occurrence and extent of these problems.

Harvesting: Under good growing conditions, harvesting can be carried out daily. Tips and older leaves can be picked or cut with a sharp knife or snips. Harvesting should be done in the cooler hours of the day to prevent wilting. Where a tip has been harvested, that runner should produce one or more new tips suitable for picking in a week.

Post harvest and storage: Leaves/tips should be washed carefully with water of drinking quality or clean seawater. They can be loosely bundled with their stems trimmed and stood upright in a small amount of clean fresh water, and if covered with a clean plastic bag, and kept cool, they should store for a day. If placed in an airtight container in a cool room or refrigerator, they can last two or three days.

Project findings/nutritional value: Samples of pumpkin and choko tips were collected for analysis from Kiribati, northern Queensland, Torres Strait Islands, Samoa, Tonga and Solomon Islands. Two to three handfuls of fresh vegetable per person for a meal serving will provide useful nutrition. Pumpkin and choko tips were notable nutritional all-rounders, being consistently high in protein, potassium, phosphorus, iron, zinc and copper. Carotenoid levels in pumpkin leaf samples from Cairns, Upolu (Samoa) and Thursday Island (Torres Strait Islands, Queensland, Australia) averaged 291, 5 and 105 mg/kg for lutein, a-carotene and b-carotene, respectively. These are moderate/medium levels for leafy vegetables.

Protein: This is important in forming muscle, cell membranes, enzymes, blood components (including haemoglobin, albumin, transferrin), antibodies, DNA and RNA. The nitrogen analyses of our samples indicated a crude protein range of 18-30%. Some samples had more protein than many legumes.

Potassium: Controls body water balance through its interactions with sodium and chloride ions, and is involved in electrical stimulation of nerves and muscles. Deficiency can cause muscle weakness, cramps and irregular heartbeat.

Phosphorus: Component of genetic material (DNA and RNA) and various fats and proteins; important role in energy production.

Iron: Important for healthy blood and energy.

Zinc: Important for immunity, growth, carbohydrate metabolism, and DNA and protein formation. Humans have around 600 different Zn-containing enzymes/proteins.

Copper: Component of enzymes, involved in iron metabolism, therefore supports production of healthy blood and generation of energy.

This table compares selected mineral nutrients in young leaves of pumpkin with leaves of chaya and *Ipomoea pes-caprae* (te ruku or beach morning glory, a sweet potato relative) growing at Paris, Beru atoll, Kiribati in 2017, and English cabbage (average of samples bought from Honiara market, Solomon Islands and Nukualofa market, Tonga in 2012) (concentration in mg/kg dry weight, except N: % dry weight).

	Fe	Cu	Zn	Ca	Mg	K	P	S	N%
Pumpkin	**88**	**19**	**107**	12800	6800	**34900**	**8100**	3200	**4.7**
Chaya	**77**	8	**79**	**33300**	**11100**	9900	2900	3600	**4.2**
Te ruku	38	**14**	52	14400	4900	**37000**	3300	3100	3.2
Cabbage	40	2	20	5700	1450	**29000**	3750	3750	2.8

Fe: iron; Cu: copper; Zn: zinc; Ca: calcium; Mg: magnesium; K: potassium; P: phosphorus; S: sulphur; N: nitrogen
Analyses conducted by the Australian Perry Agricultural Laboratory (APAL), Magill, South Australia

This fact sheet is one of a series produced for the Australian Centre for International Agricultural Research (ACIAR) funded activity "Improving soil health, agricultural productivity and food security on atolls: SMCN2014/089".

Compiled by G Lyons, G Dean, R Goebel, M Taylor, R Kiata. Layout by S Tukidia."

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BELE

Botanical name: *Abelmoschus manihot* (Malvaceae)

Location specific common names: te nambere (Kiribati), bele (Tuvalu), nambelle, slippery cabbage (Pidgin: sliperi kabis, Solomon Islands), aibika (Papua New Guinea), pele, Pacific cabbage, edible hibiscus, hibiscus manihot, neka

Plant Characteristics: Bele leaves vary in shape from round and plate-like to long and narrow. The leaves and short succulent tips are usually cooked but can be eaten fresh. Slightly older leaves are best steamed, boiled, fried or baked. It is a suitable first food for infants when boiled and mashed with root vegetables. If boiling bele a relatively small volume of water should be used, as some minerals, especially potassium, magnesium, zinc, iron and calcium are lost in the water; any water should be consumed as soup. Bele leaves (along with other leaves) are ideally served with coconut cream, which increases the uptake of beta-carotene and conversion to vitamin A. **Medicinal:** Traditionally in many SouthEast Asian and Pacific countries bele is used to treat colds, sore throats, stomach aches, diarrhoea, diabetes, and to stimulate bone repair and milk production.

Availability: This plant can grow all year in most tropical locations but growth often slows with cooler, shorter days and drier conditions.

Propagation methods: Bele can be grown from seeds or cuttings; seed-derived plants are usually slower to establish and may vary from the parent plant. Cuttings of mature wood, from 20 to 60 cm long are the most suitable for propagation, and should be planted with at least one third under the soil surface. Cuttings can be stored or transported for a few days provided they are kept in the shade, and in a little water, which should be regularly changed to reduce the possibility of stem rots.

How to grow: Bele is not difficult to grow providing the soil is rich in organic matter and water is readily available. Plants can grow in full sun preferably with some shade in the afternoon, and indeed it is shade tolerant. Mulching the plants is recommended to keep the soil moist and free of grass and other weeds. To reduce bark rots the mulch must not be in contact with the immediate base of the plant. Regular pruning will encourage growth

Threats: Bele, unlike chaya, is readily attacked by pests, which include the shot-hole beetle (*Nisotra basselae)*, cotton semi-looper *(Anomis flava)*, green coconut bug *(Amblypelta cocophaga)*, spherical mealybug *(Nipaecoccus viridis)*, corn earworm (Helicoverpa armigera), red cotton bug *(Dysdercus cingulatus)*, red spider mite *(Tetranychus urticae)* and white fly *(Hemiptera species)*. Insect pests are more damaging when the plants are growing in full sun and the weather is dry. Selecting healthy planting material and providing good growing conditions will reduce the occurrence and impact of these pests. Narrow-leaved bele varieties may be more drought tolerant than round-leaved forms (Webb, 1994).

Harvesting: Depending on the amount of bele being grown and the growing conditions, harvesting can be carried out daily. Selected leaves and even the growing tips back to the newest full leaf should be picked, ideally in the cooler hours of the day to prevent wilting.

Post harvest and storage: The leaves and tips should be washed carefully with water of drinking quality or clean seawater. They can be loosely bundled in damp paper, and if kept cool, should store for a day. If placed in an airtight container in a cool room or refrigerator, they can store for two or three days.

Project findings/nutritional value: Samples of bele for analysis were collected from Kiribati, Tuvalu, the Torres Strait Islands, Tonga, Samoa and Solomon Islands. Bele has good overall nutritional content. Two to three handfuls of fresh vegetable per person for a meal serving will provide useful nutrition.

Carotenoids: Bele had the highest levels of lutein, which is important for eye health (e.g. reducing risk of cataracts) in all of our samples, and was also high in beta-carotene (pro-vitamin A), important for vision, immunity and bone health. Carotenoids were not measured in the Kiribati and Tuvalu samples, hence their absence from the table below.

Protein: This is important in forming muscle, cell membranes, enzymes, blood components, antibodies, DNA and RNA. The nitrogen analysis of the Tuvalu sample in the table indicates a crude protein content of around 16%, which is not especially high, although well above the levels of other plants growing nearby. The bele samples from Kiribati averaged 20% protein.

Zinc: Important for immunity, growth, carbohydrate metabolism, and DNA and protein formation. Humans have around 600 different Zn-containing enzymes/proteins.

Calcium: The most important mineral for the growth and maintenance of bones and teeth. Calcium is also important for cellular physiology.

Magnesium: This mineral is important in bone formation, energy production, and nerve and muscle function.

This table compares selected mineral nutrients in leaves of bele, *Casuarina equisetifolia* and *Asplenium nidus* (bird's nest fern) growing near each other on the lagoon side of the airfield on Funafuti atoll, Tuvalu in 2014, and English cabbage (average of samples bought from Honiara market, Solomon Islands and Nukualofa market, Tonga in 2012) (concentration in mg/kg dry weight, except N: % dry weight).

	Fe	Mn	B	Cu	Zn	Ca	Mg	K	P	S	N%
Bele	56	9	26	9	**62**	**40000**	**7800**	12600	4000	3700	3.6
Casuarina	40	10	17	3	37	9000	1830	8300	1010	1450	1.7
Asplenium	13	8	**65**	3	22	17100	5400	**39000**	3100	1100	1.7
Cabbage	40	23	12	2	20	5700	1450	**29000**	3750	3750	2.8

Fe: iron; Mn: manganese; B: boron; Cu: copper; Zn: zinc; Ca: calcium; Mg: magnesium; K: potassium; P: phosphorus; S: sulphur; N: nitrogen. Asplenium, although low in iron, manganese and nitrogen, looked healthy with no chlorosis. Our other samples were similar. This plant appears to be, like hedge panax, very iron efficient.

Analyses by Waite Analytical Services, University of Adelaide, South Australia

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Compiled by G.Lyons, G.Dean, R.Goebel, M.Taylor, R.Kiata. Layout by S.Tukidia.

CHILLI

Botanical name: *Capsicum spp.* (Solanaceae)

Location specific common names:), *C. frutescens (*Birdseye and Tabasco*)*, te beneka (Kiribati), chili, chile

*C. annuum (*Sweet peppers or capsicum)

Plant Characteristics: Chilli plants are small bushes that usually grow for a year or more in warm locations. They are suitable for container growing. There are many recognised species and varieties ranging from sweet capsicums that have no heat to the fieriest hot-fruited forms. Birds are not affected by the heat component (capsaicin) in chilli, therefore birds, after eating the fruits, scatter seeds, allowing volunteer plants to grow often in unusual places.

Uses: Leaves and young tips can be used fresh or in cooked dishes. They have a mild distinctive flavour that is not hot to taste. **Medicinal:** Juice from chilli fruits and leaves has been used traditionally in some countries for skin problems, including psoriasis and pain. Capsaicin is the most studied active compound in chilli plants, and has been shown to be useful against pathogenic bacteria, cancer, heart disease, diabetes, obesity and arthritis.

Availability: This plant can be grown all year in most tropical and sub tropical areas. It has been grown in Kiribati and Tuvalu for a long time and is well accepted, although more for the fruits than the leaves.

Propagation methods: New plants are produced from seed. Plants often self-seed and with a little care, the seedlings easily transplant.

How to grow: Chilli plants can be easily grown in large pots. A pot of 20 litres capacity or larger should be used, filled with a well drained, composted soil, in which four seeds or young plants can be placed. These plants like more alkaline soils than most tropical plants so coral sand in the mix will promote growth. They are deep rooted but even when established require occasional watering during drier conditions. Chilli plants will grow in full sun but a little shade produces larger, more tender leaves. For a continuous supply of leaves two or three staggered plantings of ten or more plants will be required each year. Leaf production is reduced when the plants fruit.

Threats: Pests like scales and spiralling whitefly will reduce plant vigour, resulting in smaller leaves or even death of the plant. Scales can be controlled by reducing ant populations with well mulched, moist soils. Spiralling whitefly populations can be decreased by mulching the soil with light coloured materials such as shredded paper and spraying the undersides of leaves with jets of water.

Harvesting: Leaves and tips can be neatly picked or cut with a sharp knife. Harvesting in the cooler hours of the day will prevent wilting. Leaves should not be harvested too often (a good guide is to remove no more than a quarter of the leaf area/volume/weight) as plant vigour may be affected, and fast growing younger plants produce the best leaves.

Post harvest and storage: Leaves should be washed carefully with water of drinking quality or clean seawater. If loosely bundled in moist paper and kept in a cool location, leaves should keep fresh for a day or two. If placed in an airtight container in a refrigerator, they can last for up to a week. Chilli leaves are firm and therefore can be frozen.

Project findings/nutritional value: Samples of chilli leaves for analysis were collected from Solomon Islands, Samoa and the Torres Strait Islands. About two handfuls (100 grams) of fresh leaf per person for a meal serving will provide useful nutrition.

We found chilli leaf to be a consistently rich source of potassium and copper, as well as being relatively high in most other minerals and carotenoids: for example, at a Burns Creek, Honiara (Solomon Islands) site, chilli leaf was found to contain 829, 32 and 340 mg/kg dry weight of lutein, alpha-carotene and beta-carotene, respectively, all excellent levels.

Carotenoids: Lutein is important for eye health (e.g. reducing risk of cataracts) and beta-carotene (pro-vitamin A) is important for vision, immunity and bone health.

Potassium: Controls body water balance through its interactions with sodium and chloride ions, and is involved in electrical stimulation of nerves and muscles. Deficiency can cause muscle weakness, cramps and irregular heartbeat.

Copper: Component of enzymes, involved in iron metabolism, therefore supports production of healthy blood and generation of energy.

This table compares selected mineral nutrients in leaves of Chilli and "sandpaper cabbage" (*Ficus spp.*) grown together at Aruligo, Guadalcanal, Solomon Islands in 2012 and English cabbage (average of samples bought from Honiara market, Solomon Islands and Nukualofa market, Tonga in 2012) (concentration in mg/kg dry weight, except N: % dry weight).

	Mn	B	Cu	Zn	Ca	Mg	K	P	S	N %
Chilli	32	72	**26**	22	19900	4600	**50000**	4900	3800	3.2
Ficus	26	54	8	18	**25000**	3200	22000	2100	2100	3.1
Cabbage	23	12	2	20	5700	1450	**29000**	3750	3750	2.8

Fe: iron; Mn: manganese; Cu: copper; Zn: zinc; Ca: calcium; Mg: magnesium; K: potassium; S: sulphur; N: nitrogen
Analyses conducted by Waite Analytical Services, University of Adelaide, South Australia

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PURSLANE

Botanical name: *Portulaca oleracea* (Portulacaceae)

Location specific common names: te boi (Kiribati), Katuli (Tuvalu), pigweed, little hogweed, duckweed, parsley, red root, verdolaga. *P. lutea* has rounder, fleshier leaves and *P. australis,* te mtea (Kiribati) or pigface, has longer, fleshier leaves than the others. All three species are edible.

Plant Characteristics: Purslane has smooth, reddish, mostly prostrate stems and green, succulent leaves, with yellow flowers. It is a fast-growing annual, thrives without fertiliser and tolerates drought and salt. Like some other *xerophytes* (plants that thrive in dry conditions) it employs an unusual photosynthetic strategy: although it uses mostly the "C4" photosynthetic pathway, when drought-stressed it switches to an alternative pathway: crasulacean acid metabolism (CAM). When this pathway is used, the leaves trap carbon dioxide at night, converting it to malic acid, and during the day the malic acid is converted to glucose. Hence leaves harvested in early morning have 10 times the malic acid of leaves harvested in late afternoon, and taste more tangy.

Uses: The leaves are tasty and nutritious. They contain some oxalate, which is reduced by cooking. Nevertheless, levels are low (similar to spinach) and purslane can be eaten raw, for example in salads. It can be cooked by stir frying or steaming. It is renowned for its **Medicinal** applications: It contains the highest levels of desirable omega-3 fatty acids of any plant analysed (for example, 0.01 mg/g of eicosapentaenoic acid, EPA). These are essential for human growth, development, maintaining immunity and lowering disease risk. It also contains numerous other beneficial phyto-compounds (including polyphenols, sterols, anthocyanins, carotenoids) and is used in various countries for an astonishing range of medical/health purposes. These include, among others, application against diabetes, cancer, heart disease, inflammation, fever, oxidative stress, low density lipoprotein cholesterol, high blood pressure, Alzheimer's disease, bipolar syndrome, colitis, microbial pathogens, liver toxins, and it can stimulate lactation. Indeed, the name *Portulaca* means "to carry milk".

Availability: Purslane probably originated in India. It is remarkably adaptable and is now flourishes in all but the coldest climates worldwide. It is common on most atolls of Kiribati and Tuvalu, often growing unplanted on unused land.

Propagation methods: It can be propagated by seed and cuttings. One plant can produce up to a quarter of a million seeds, which can remain viable for up to 40 years. Once established in a particular area, it will return year after year as long as it is allowed to flower and produce seeds.

If hand planting, just spread the seeds on the soil surface, rather than bury them, as they require light to germinate. Place stem cuttings on the ground, water and they will take root.

How to grow: As purslane does not like wet (or cold) conditions, water sparingly until the plants are established. They grow best in sunny situations.

Threats: Shade weakens purslane and makes it more susceptible to pests and diseases such as aphids (which can be removed by spraying with soapy water) and fungi (especially in wet seasons).

Harvesting: Any of purslane's succulent leaves can be used for eating. The older leaves will taste more sour than the younger leaves.

Post harvest and storage: The leaves should be washed with clean water and stored in a cool, shady place, and ideally eaten soon after picking.

Project findings/nutritional value: Purslane is a wild, edible, nutritious food. Samples were collected in Tuvalu and Kiribati. Purslane is particularly high in magnesium. The level of 41,000 ppm found in the sample collected at Chevalier College, Abemama, Kiribati is the highest magnesium level we have found in plants we have analysed back to 2007. This plant is also an excellent zinc accumulator, similar to cassava leaves. The high omega-3 fatty acid content of purslane was noted above. About two handfuls of leaves/stems (100 grams) per person for a meal serving will provide useful nutrition. Purslane is notable for:

Magnesium: This mineral is important in bone formation, energy production, and nerve and muscle function. Furthermore, it has anti-inflammatory effects, and magnesium deficiency is a risk factor for obesity, metabolic syndrome and diabetes.

Zinc: Important for immunity, growth, carbohydrate metabolism, and DNA and protein formation. Humans have around 600 different Zn-containing enzymes/proteins.

Iron: Important for healthy blood and energy.

Carotenoids: Purslane leaves are a good source of pro-vitamin A: other studies have found levels around 1320 international units/100g fresh weight. This is important for vision, immunity and bone health.

This table presents selected mineral nutrients in leaves of purslane growing on coralline soil in the front garden of a house in the town centre on Funafuti Atoll, Tuvalu in August 2014. The other plants were growing nearby. English cabbage (average of samples bought from Honiara market, Solomon Islands and Nukualofa market, Tonga in 2012) (concentration in mg/kg dry weight, except N: % dry weight).

	Fe	Mn	B	Cu	Zn	Ca	Mg	K	N
Purslane	**70**	5	50	14	**103**	16900	**22000**	**31000**	3.3
Ceylon spinach	31	9	33	11	**92**	**21000**	14800	**36000**	3.5
Ofenga	33	19	26	14	**61**	**23000**	**17700**	7000	3.4
Hedge panax	33	56	38	6	**71**	**25000**	6700	12000	2.7
Chaya	**76**	19	19	9	42	16100	5500	16400	**5.1**
Cabbage	40	23	12	2	20	5700	1450	**29000**	2.8

Fe: iron; Mn: manganese; B: boron; Cu: copper; Zn: zinc; Ca: calcium; Mg: magnesium; K: potassium; N: nitrogen
Analyses conducted by Waite Analytical Services, University of Adelaide, South Australia

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Nutritious leafy plants: also valuable for soil health

Introduction: Factsheets 1-12 have demonstrated that a range of nutritious perennial leafy vegetables can be found and successfully grown on Pacific atolls. However atoll soils, being almost entirely derived from coral, are low in many nutrients particularly potassium, iron, manganese and copper. Availability of nutrients is further exacerbated by the high soil pH. Being sandy in nature, these soils also have a low ability to hold both water and nutrients. This, combined with commonly high levels of salt, creates a tough growing environment for plants. It is important that these constraints are overcome to provide optimal conditions for growing nutritious leafy vegetables.

Inorganic fertilisers are banned on many atolls and traditionally soil fertility for growing crops such as Giant swamp taro has been improved with the addition of compost. In addition to providing and holding necessary plant nutrients, compost also buffers against drought, salinity and high soil pH constraints.

Acanthophora seaweed from Bonriki, Tarawa, Kiribati

Current compost making uses varying proportions of brown and green leaves with addition of animal manure to provide a lot of the necessary nutrients. However on many atolls there are limited numbers of pigs and chickens and manure is not readily available. In addition, unless housed in a pen with a floor, the manure is mixed and diluted with soil. For many atolls alternative compost ingredients are required instead of animal manure.

A new approach to making compost: Following on from preliminary work on Taveuni island, Fiji one of the aims of the current ACIAR atoll soil health project is to improve the science behind making compost. In conjunction with the evaluation of plant leaves for human consumption the project is also assessing the comparative nutritive value of leaves as ingredients in compost.

Results from soil tests highlight likely nutrient deficiencies and to fix these issues, suitable leaves and other inputs are added to improve the composition of the compost. Thus, rather than just making compost with whatever material is available, a more targeted approach is being taken. For example, low iron in soil typically shows as yellowing between the veins of leaves (interveinal chlorosis) in susceptible plants. Mineral analyses of yellow beach pea (te kitoko/saketa sega; Factsheet 7) and chaya (te tiaia; Factsheet 3) have consistently demonstrated high levels of iron in their leaves and so both plants are good accumulators of this nutrient. When soil iron levels are low, leaves from these species can thus be targeted when making compost. We are therefore terming this ***targeted composting***.

What should I be adding to my compost?

When making compost, alternating layers of "brown" and "green" materials are added. For further details on how to get started in making compost see the ACIAR/SPC factsheet, "*Making compost for healthy atoll soils*".

The "brown" component of compost is frequently the fallen leaves of breadfruit (*Artocarpus spp*; te mai/mei) with premna (*Premna serratifolia*; te ango/valovalo) and guettarda (*Guettarda;* te uri/pua) leaves also commonly used, depending on what is most readily available. Mineral nutrient levels in brown breadfruit leaves are presented in the table below. Premna and guettarda leaves are similarly low in most nutrients.

The "green" leaf component used most regularly in compost is beach cabbage (*Scaevola taccada;* te mao/gasu). As with the commonly used brown leaves, mineral tests show only low to moderate levels of nearly all nutrients. The existing use of beach cabbage in compost therefore appears to be based on advantages of abundance and ease of harvest rather than targeted mineral composition. To enhance mineral levels of compost other inputs of higher nutritive value, in addition to the standard brown and green leaf components, are thus required.

Potassium is generally the most limiting macro-nutrient in atoll soils. While green leaves of purslane (te boi/katuli; Factsheet 12) and to a lesser degree, pisonia (*Pisonia grandis;* te buka/pukavai –see table below) and chaya (Factsheet 3) contain reasonably high levels of potassium, this is insufficient to compensate for the generally low soil levels. This deficiency however can be largely overcome through the addition of ash which has very high levels of potassium. This is not surprising as ash is the concentrated by-product of large quantities of plant material. Of the different ashes tested to date, that from burning coconut husks and shells contains by far the highest amounts of potassium. Fortunately this is a very common fuel source for cooking fires. If available, other excellent sources of potassium are the seaweeds (te tiwiita/limu) *Acanthophora spp* and *Sargassum polycystum.* The samples in the table below were collected from Tarawa and Funafuti respectively. In contrast, seagrass (*Thallasia hemprichii*; te keang/mouku ote tai) is much lower in potassium.

Nitrogen is best provided in marine and animal by-products such as fish waste and animal manure. Data in the below table for fishmeal are from the after-processing by-products of fish heads, guts, scales and bones sourced from Levuka, Fiji. Local fish waste should be similar in mineral composition. From preliminary overseas data it also appears that the nutrient content of dried sea cucumber (lollyfish; *Holothuria atra*) is comparable with fishmeal. In the absence of these inputs the best plant sources of nitrogen are chaya (Factsheet 3), drumstick (Factsheet 4), yellow beach pea (Factsheet 7), purslane (Factsheet 12) and pisonia (table below).

Iron deficiency is very common in plants growing in atoll soils. Fishmeal, ash and seaweed all have high iron levels (table below) and there are also moderately high amounts in purslane, yellow beach pea and chaya (see relevant factsheets). It is also likely that soil iron levels can be increased with addition of small amounts of ground-up rusted iron (e.g. 2 mm). While iron oxide is commonly recognised as being unavailable to plants there is anecdotal evidence from trials in Kiribati that addition of rusted iron particles will increase the level of available iron and thus assist in alleviating iron deficiency. Trials are evaluating whether this effect can be further enhanced by adding rusted iron at the beginning of compost making.

Beach cabbage being prepared for compost -Tanaea, Tarawa, Kiribati

Manganese and **copper** deficiency are probably underestimated in their prevalence in atoll soils. Both minerals are present in relatively high levels in ash and to a lesser degree in the leaves of pisonia. Of note, pisonia is often used as a compost ingredient in Tuvalu. Yellow beach pea will also provide useful amounts of manganese.

Phosphorus and **zinc** have been shown to be often present in adequate to high levels in soil tests conducted to date. Given the expected high tie up of both elements in alkaline soils, this result has been surprising and additional tests using different soil P testing methodologies are being undertaken. Phosphorus and zinc are both present in ash and fish meal in relatively high levels. Of note, yellow ilima (*Sida fallax;* te kaura/akata), which is commonly added to babai/pulaka compost, is a good source of both nutrients (see table below).

Sulphur and **boron** are not commonly deficient in atoll soils. Drumstick leaves are recognised as being exceptionally high in sulphur content (Factsheet 4), however the level in seaweed, particularly *Acanthophora* is higher still. Ash, seaweed and seagrass are also rich sources of boron (see table below). The highest levels of boron in terrestrial plants are found in the brown leaves of breadfruit, guettarda and premna and so all compost made using these brown leaves should contain sufficient boron.

Pisonia from Utiroa Tab North, Kiribati

Pisonia from MELAD nursery, Abemama, Kiribati

Note - It is evident that ash from cooking fires, particularly from burning coconut husk and shells, can provide good levels of most plant nutrients. However large amounts of ash added to compost may cause nutrient imbalances due to the additionally high levels of chloride, sodium and magnesium (more of something isn't always good). As part of this ACIAR project we are conducting trials to evaluate the optimal levels of ash that can be safely added to compost. Until these trials are completed, addition of ash should be limited to 2 shovels (4-5 kg) sprinkled in a cubic meter compost heap. In the meantime to help overcome any possible nutrient inadequacies, try to source a small quantity of pig manure to boost mineral levels. Soil tests have also shown that the soil from around tethered pigs is comparatively high in available potassium and nitrogen and this can be added to compost. It may even be useful adding a layer of chopped brown leaves in the pig run to help soak up urine.

Also note that not all of these suggested plants will be readily available. Seaweed for example is seasonal when washed ashore. Some plants such as purslane and yellow ilima may be present but, being herbaceous, are only available in smaller quantities. Inability to supply one or more inputs should not be a problem if other listed options can be substituted.

The data (next page) provide an indication of the most useful ingredients when making compost. The final proof will be through comparative testing of composts made from different ingredients and this is currently being undertaken in pot and field trials conducted by ACIAR. Different vegetables will also have different nutrient requirements; with further trials we will be able to provide variants to compost formulation for different crops.

The table below presents the mineral content in leaves of plants and other materials not listed in previous ACIAR factsheets and currently used or showing potential for making compost. Each data point is the average nutrient content of between 2 and 11 samples collected from Kiribati and Tuvalu between 2014 and 2018. Data for calcium, magnesium and sodium are not presented as these minerals are in ample supply in the soil. (Concentration in mg/kg dry weight, except N: % dry weight).

	N %	P	K	S	B	Cu	Zn	Mn	Fe
Breadfruit	1.1	1930	1535	1750	74	3	12	11	38
Beach cabbage	1.9	2525	8425	3338	41	3	33	10	25
Pisonia	3.7	2883	18883	3617	45	18	19	32	53
Yellow ilima	3.0	5050	11833	1990	30	4	61	19	38
Acanthophora	1.6	967	47200	42333	410	2	10	5	129
Sargassum	1.2	1350	57200	15500	235	1	28	27	95
Seagrass	2.7	2450	22500	6800	512	4	7	7	62
Fish meal/waste	8.3	10800	6900	na	na	5	102	25	836
Ash -coconut husk	0.1	14688	84994	2352	337	99	131	86	235

N: nitrogen; P: phosphorus; K: potassium; S: sulphur; B: boron; Cu: copper; Zn: zinc;
Mn: manganese; Fe: iron; na: not available
Analyses conducted by APAL Laboratory, Adelaide; Waite Analytical Services, University of Adelaide, South Australia; and Fiji Agricultural Chemistry Laboratory, Nausori, Fiji

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