Issues facing larger-scale taro growing in New Zealand

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Abstract

Taro was originally brought to Aotearoa/New Zealand by the first Polynesian settlers, and is a cultural treasure or "taonga". Taro has recently been grown commercially in New Zealand for its leaves in sheltered conditions or greenhouse cultivation under dryland conditions. Taro plants in submerged wetlands conditions have been shown to thrive in Waikato streams, surviving successive frost events throughout the winter season, in 'weed free' conditions. Wetland taro growing in New Zealand needs to be explored further with a view to growing at larger scale. Potential environmental benefits include reducing excess nutrient runoff, mitigating sediment loss, and phytoremediation. Issues/problems facing larger-scale taro growing in New Zealand are examined with a particular attention to growing wetland taro using traditional Polynesian and/or organic farming methods used extensively in Hawai'i today. These methods may have been used in New Zealand's historic past. Some specific issues addressed include 1) dryland/wetland taro growing methods, 2) extreme flood events, and 3) pests. General issues and possible approaches to larger-scale taro growing in New Zealand are discussed with an emphasis on wetland rather than dryland taro production. This study narrows down the scope for larger scale trials addressing the specific issues raised by growing conditions in New Zealand. The work also presents a way forward to renew the value of a largely-forgotten plant.

Additional keywords: taro, taonga, cultivation, irrigation, frost, flood

Introduction

Taro (*Colocasia esculenta* (L.) Schott) is a widely distributed starchy-root and green-vegetable crop in the humid tropics and subtropics. Taro's range extends into the temperate zones of East Asia, southern Africa, Australia, and as far south as New Zealand.

The genetic and cultural origins of taro in New Zealand and other parts of the Pacific (including Hawai'i) are discussed by Matthews (1985, 2014). Matthews (1985) reports the distribution of variants of taro grown in and near swamps, pa sites, near pits and/or in terraces, streams, regenerating forests, and stream banks, at archaeological sites in the Northern parts of New Zealand. In the mainstream of modern crop production and Maori cultural practices, taro has been largely forgotten in New Zealand but there are still places where they may have been grown continuously since pre-European times, or where old taro plantings have persisted in waterways. More recently, new varieties have been introduced and cultivated in some districts; some of these may be re-introductions of the same clones introduced in ancient times, carried by modern immigrants from Polynesia, or imported for vegetable markets around the country. Taro is grown in many home

gardens, and also at a number of marae, for its cultural and nutritional value. Taro is commonly a minor summer crop grown in New Zealand for its leaves. Taro is a familiar crop for Pacifika and Asian people and there is a renaissance in interest among Maori.

Taro is grown commercially on a large scale in Pukekohe, near Auckland, and Ngataki in the Far North. It is grown for its leaves in plastic houses with fertiliser in Pukekohe, or with shelter to protect from frosts at Ngataki. There has been interest year-round production of taro leaves in northern New Zealand and newer cultivars have been trialled. High quality leaves have been grown successfully in plastic tunnel houses during late spring, summer and autumn (Bussell and Triggs, 2010). Recommendations for obtaining higher leaf yields from mid-winter to early spring include increasing greenhouse temperatures, using raised beds and possibly utilising cool-tolerant Japanese cultivars (Bussell, 2006). The Japanese taro cultivars of temperate origin produced leaves throughout the period from May 2007 to May 2008. More common tropical cultivars grown in New Zealand produce leaves between mid-winter and early spring (Bussell and Triggs 2010). It is believed to be not possible to grow Pacific Island cultivars in New Zealand with large corms (Bussell and Goldsmith, 1999; Bussell et al., 2003) because the growing conditions (not high enough rainfall or too low mean temperatures) do not allow the development of large size corms (up to 1 kg). Only taro corms, not leaves, are imported from the Pacific Islands, although some commercial production of taro corms has been successful in the Far North. Soil residues and unwanted organisms associated with taro imported from Samoa are a concern, and new treatments to remove these are being trialled by Plant and Food Research (2016). These issues give further motivation for investigating a larger scale taro corm production in New Zealand.

As a wild plant, taro is originally semi-aquatic, and thrives in semi-submerged/emergent conditions. All taro cultivars love water but generally do not like to dry out. Conditions that favour large size and high rate of growth of leaves appear to include shelter, heat, and wet boggy ground. Taro appears to tolerate a very wide range of low to high-nutrient conditions, and has a natural ability to absorb and respond to nutrients when available. It also tolerates a wide range of light conditions, and responds positively to full sunlight when water is not limiting. Shelter can increase ambient temperature and humidity required for effective growth. The taro petiole is spongy in texture, and has numerous air spaces which presumably facilitate gaseous exchange when the plant is grown in swampy or flooded conditions. A major problem with growing taro in open ground in New Zealand is the adverse effects of frosts. Taro survives frosts in many areas of New Zealand but with growth setback. Taro can usually survive even when frosted down to soil level. Parshotam *et al*. (2017) showed that taro grown in small streams entering the Waikato river survive through the winter season, and experience less setback than plants growing away from a stream. The plant may have the ability to take up and distribute warm water to the leaves to reduce the adverse effects of frosts. Greater air movement near a stream may also reduce frost close to the stream. Although its growth during the winter is very limited in northern New Zealand, taro can quickly grow to a

large size during summer, from a standing population of vegetative shoots. There have been no serious trials in New Zealand of growing taro in and around other water bodies and contrasting wetlands conditions.

As a world plant, taro is grown in two distinct soil environments – flooded, "paddy" soil conditions in water-confining areas and non-flooded "field" soils that receive moisture from rainfall or irrigation. All cultivars of taro can be grown under non-flooded conditions but not all can grow well in flooded soil. Beyond Hawai'i most of the world's taro production is in non-flooded field conditions and Hawai'i's flooded taro cultivation was unique in the Pacific. It is usually grown in the wet areas of the islands based on the accessibility of stream or spring water sources or rainfall. In contrast to Parshotam *et al*. 2017 who raised the question of whether taro may grow in Waikato streams, Teves (2015) questions whether good quality taro (known as upland taro) may actually be grown on dry land.

Polynesians introduced taro to as far as New Zealand but New Zealand is at the extreme end of where taro can grow successfully. Polynesian traditional methods of growing wetland taro in Hawai'i could be useful for trialling growing taro in New Zealand near and around streams, or where there is running water and taro could have the ability to withstand the adverse effects of frosts in 'weed free' conditions. Some of these methods may even have been used historically (Barber, 2001) since New Zealand Maori horticulture is notable for the successful introduction of shifting tropical dry cultivation into a temperate Oceanic zone. Both Barber (1984) and Johnson (1986) were of the opinion that ditched swamps in New Zealand were devoted to specialised taro cultivation. Jones suggested that ditches were used for taro and the beds between for kumara. The importance of taro to the Maori economy of near-subtropical north New Zealand was discussed by Bulmer (1989). Groube (1967) referred to the failure of researchers to consider taro from (precontact) northern New Zealand "as a significant agricultural food". Barber (1984) refers to archaeological investigations into possible northern wet taro gardens that have been undertaken since the late 1960s. Further trials near and around water bodies need to be conducted.

Deliberately planting taro in and near streams prevents the adverse effects of frosts (Parshotam *et al*. (2017). As well as the general issues/problems arising from growing wetland taro, planting in or near streams raised other issues that need to be addressed. These include extreme flood events and pukeko damage.

This paper reports on some field trials and issues/problems with growing taro, which need to be addressed before planting out at larger scales. Results (as field observations) for trials in the Waikato region include sites at 1) Narrows Experimental Research Station, adjacent to the Narrows Bridge in Hamilton, 2) a main road drain near at Patetonga, Waikato, 3) a dairy farm property in Waitakaruru, Waikato. This study is necessary for future controlled studies on growing taro in temperate climates, with a better understanding of the general and specific issues and problems faced.

Materials and Methods

The variant of taro plants and source are as described in Parshotam *et al*. (2017). In summary, this variant may be recognised in

the field simply as with red petioles (or leaf stalks) and rounded blades, simply described as an RR variant (Matthews, 2014). These plants were planted out in Jan-Feb of 2017 at numerous sites (including sites in the South Island). Only results from three sites in the Waikato region and some of the trials are reported here. These generally concern a simple floating island concept, flooding events and pukeko uprooting plants: 1) the Narrows Experimental Research Station, in Hamilton described by Parshotam et al. 2017, 2) a stream alongside a main highway in Patetonga, 3) a dairy farm in Waitakaruru.

Photographs were taken throughout the year when possible.

Results and Discussion

Specific Issues

Floating island concept/hydroponics

Floating islands are used for growing taro in many parts of the world where there is a scarcity of land. They also have potential for nutrient removal from ponds.

Taro plants faced stiff competition from grasses in ponds. Root growth looked good initially (see Figure 1). However plants then disappeared altogether possibly due to pukeko and/or dislodging following a flood event.

i) **ii)**

Figure 1: i) Taro planted on a floating grass-wetland in Waitakaruru on April, 2017, and, ii) three weeks later.

A further trial took advantage of a locally available spoiled silage bale to try and get around two problems: pukeko uprooting and grass competition. A simple structure was made to float the plants in water and attempt to grow them in a hydroponics-like situation (see Figure 2). However, after two weeks the plants were making new roots but collapsed due to lack of support. Although this was only a first attempt, it does appear as if taro might grow well directly in water using better structural support.

Taro grows in a controlled hydroponic system (e.g. Ares *et al*., 1996) and may be grown for leaves, not corms.

i)

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Figure 2: i) and ii) Taro planted in a simple floating structure, planted in April-May, 2017 and, iii) plants two weeks later.

Flooding

Taro were planted in a stream entering the Waikato River (see Figure 3) and a ditch along the main road highway in Paretonga in Jan-Feb, 2017 (see Figure 4). In both cases, three days after an extreme flood event in late autumn, 2017, it was observed that the plants 'bounced' back. The young shoots appeared to be undamaged. A similar observation was made with taro plants grown in the main highway ditch after the same flood event. Most were not dislodged and bounced back within days.

It is known that some varieties are not able to remain standing after a single flood event. Farmers in Hawai'i report floods smothering their taro patches with mud and silt, which turns their crop watery and spongey. And these leaves are not marketable and there are dramatically reduced yields for at least a year. A greater number of taro varieties need to be trialled in areas where flood events are likely.

Pests

Although considered an indigenous bird some view them as a pest. There are major problems getting taro plants established in wetlands areas with pukeko (Australasian swamphen, *Porphyrio melanotus*) around. Pukeko are found throughout New Zealand, although less common in drier regions. They are typically found near sheltered fresh or brackish water (e.g. vegetated swamps, streams or lagoons), especially adjacent to open grassy areas and pastures. Pukeko are known to eat garden vegetables and crop plants, although they more commonly eat stems, shoots, leaves and seeds of grasses.

In one trial area around a pond at the Waikato Experimental Research Station, using a black ornamental variety of taro, most of 40 plants had disappeared with pukeko leaving very few plants with intact roots and tops. During summer months when established and new taro plants were growing on dry land about 50m away from ponds, pukeko spent a lot of time running around in the (1.5m) taro 'forest' habitat. There was damage done by pukeko knocking down rare taro flowers. At the Thames trial site, numerous planted taro plants had disappeared, presumably uplifted by pukeko. Trial sites where there were no pukoko around survived and thrived. In our trials there was no evidence of pukeko damage of taro grown in moving streams.

The damage to taro by pukeko does not appear to be documented in the literature. Damage by a variety of certain species of swamphen (Hawaiian gallinule) has been reported in Hawai'i by some farmers (Josephine Hoh, Botanical manager, Waimea Valley, *pers comm*). However, the birds are endangered in Hawai'i so their numbers are much lower.

To avoid pukeko damage, plants need to be planted deeper and pressed hard around the base. In addition, tying a bamboo stick to the taro plants at planting makes it more difficult for them to dig out plants.

General Issues

Dryland vs Wetland cultures of growing

There are two major ways taro is grown and the two growing cultures present two different sets of issues discussed by Evans (2008). There is non-flooded culture (also known as "upland" or "dryland" culture), and there is flooded culture (also known as "wetland" or "lowland" culture). Weed control is the greatest challenge in growing upland taro. Growing taro is very labour intensive with little use of mechanisation and tillers may be used. Newer and more modern methods of growing upland taro using mechanisation, drip irrigation, spacing, nutrient management, hybrids of traditional and modern systems of growing are discussed by Teves (2015). Modern digital technology makes water supply and control a much less labour-intensive option, so while upland taro production systems are well known for requiring arduous manual labour, it may be possible to reduce labour requirements, mechanical requirements, and fertiliser inputs with a careful mix of modern technology, organic farming techniques, and integration with other crop production systems. By definition, dryland includes land that is bone dry, to land that is boggy. Wetland taro growing involves preparing an area of land to hold water, and diverting streams through this field, or having a source of running water through the field with a

flow-through drainage system. Taro plants are usually planted in dry soil (i.e. the land is drained first) which is prepared with organic matter and the land is flooded. Water should always be flowing through the taro field. If not, it will get hot, stagnant, full of algae and root rot will occur. If there is not enough water for a flow-through system, one can switch to a raised-bed system rather than true "wetland" farming. Taro can also be grown in flooded furrows or on a ridge with flooded furrows.

In Hawai'i, taro grown in water is slower growing and more prized. Stream temperatures are generally lower than ambient air temperatures. There are two crops of taro in a year on dry land whereas there is only one crop of taro grown in wetland. Upland taro is better adapted to uses such as table taro and usually produces a lower quality *poi* (mashed/pounded taro) taro, and fermentation process can take a different path.

Traditionally in New Zealand, taro grown on land was more prized and considered by Maori to be only for "important people", one reason presumably was because it was so easy to grow it in streams. Another reason could be how it was traditionally prepared and so quality may have been an issue. It is important for cultural reasons to have a better understanding of these differences in agronomic practices.

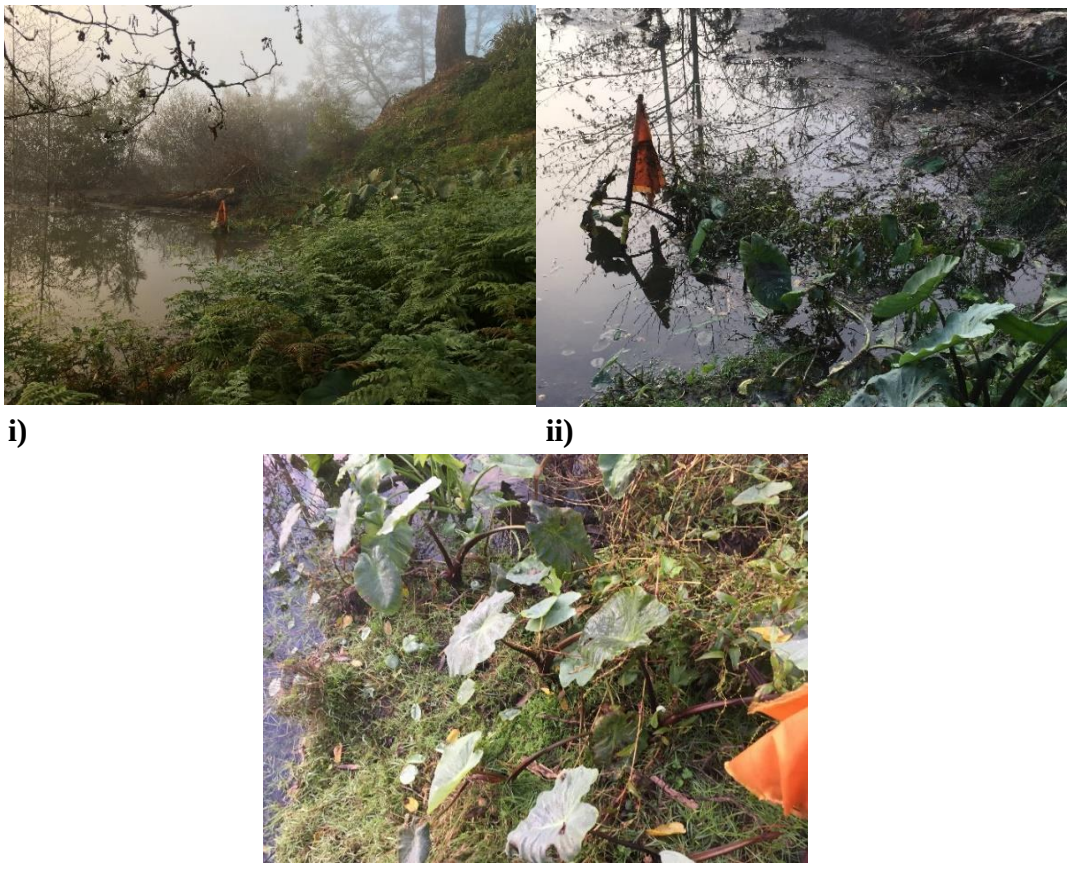

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Figure 3: i) and ii) Taro plants submerged under late autumn flooding of the Waikato River and iii) three days after the flood event and after the water had subsided. Note the position of the flag.

i) ii)

Figure 4: i) Taro planted in Jan-Feb, 2017 on the stream bank alongside a main highway Patetonga, during a late autumn flood event (photo taken March 11, 2017) and, ii) after all frost events (photo taken 12 September, 2017).

Weeds

Our trials (results not shown) show taro growing extremely well in boggy ground with competition from weeds and grasses. There are no weed issues apart from competition with watercress of taro growing submerged in a stream. Wetland taro generally does not like algae but does very well with nitrogen fixing azolla weed. Dryland taro needs mulch around the base to control weeds, retain water and keep roots cool.

Diseases

There are many diseases affecting taro that are reported in the international literature. The dasheen mosaic potyvirus infecting taro dasheen mosaic virus infection, has been observed on the leaves of one Japanese and two traditional New Zealand cultivars of taro (Colocasia esculenta Schott) grown in the Auckland area (Pearson *et al*., 1998).

Planting and spacing

There needs to be a better and more consistent way of preparing taro tops for planting in future trials and this was not considered in trials by Parshotam (2017). These include the depth of planting and vigour of the plant which seems to depend on the age of the main or mother plant from which the cutting is taken. With regard to the latter, there is a practice of notching the mother plant at the base to mark the number of the year of planting and discarding it after three years.

Taro top, as used for planting; propagating material; part of the plant used for replanting after removing leaves and corms, needs to be planted quite deep, at least 6 inches deep if a large corm is required, and shallow for multiple corms. It is usual to strip off any leaves and the base of the corm, which may harbour diseases.

Taro does not grow downwards like a carrot but upwards and so mounding becomes necessary to form a big root if

grown on dryland. If this is not done, there may be lots of smaller tubers at the surface. Soil mounds may also be made in the water and taro planted directly in these. Taro for leaves is usually planted separately from taro grown for its roots. Frost damage removes leaves effectively reducing nutrient flow to the corm. This does not allow the completion of the cycle of drawing nutrients away from the leaves to root formation.

For taro grown on dry land, it becomes necessary to use frost cloth for root formation. Growing taro in a temperate climate amounts to one month less of active growing during a year (Evans, 2008). Not all taro cultivars mature at the same time. It is currently believed that harvest should begin approximately 28 weeks when the leaves begin to die down. There needs to be further trials to study the full cycle of taro leaf and root growth in New Zealand. Trials were conducted to determine the effect of irrigation, size of planting propagule, harvest time, plant density, and nitrogen nutrition on cormel yield and quality of Japanese Taro by Scheffer *et al*. (1999). Japanese taro is more cool tolerant than Pacific Island taro, which prefers a long growing season and high temperatures.

Tubers sometimes need to be lifted and stored in a cool dry place over winter. This might happen if a plant is dug up, and divided from the main plant before winter. There are some chances that corms may in fact rot during the winter period. Wensor (pers comm.) describes a Maori tradition of saving small corms over winter would be to "wrap up the corms over winter' in karaka leaves until the corm would 'eat' the karaka leaves. This practice has not been investigated. Our trials show that small corms may be best grown in pots to a certain size and kept in a glasshouse before putting them out in the field. A corm with a new shoot and young opened leaf cannot be planted too deeply but a corm with an eye can be.

For taro grown in streams and wetlands in New Zealand, further trials are required on planting at different times of the year. Taro in New Zealand is usually divided and planted in November after frost events.

Potential invasiveness.

Although the invasiveness of taro is reported in some tropical environments, it is unlikely that it would become invasive in New Zealand due to frosts down to river level that keep the plant surviving rather than thriving. Roundup kills the leaves but not the plant. The plants may be removed from a property at any time.

Wetlands management and erosion control

Growing taro in farm streams and ditches might be a productive use of dairy farm streams and drains, add to on-farm diversification options, and potentially increase locally grown, all year round, fresh taro leaves' availability in New Zealand. Grown under the conditions proposed, taro would be a zero-input crop requiring zero irrigation, fertiliser, and management. Taro may provide an on-farm biological mitigation option for nutrient management in streams. It has been shown by Bindu *et al*., 2008) that subsurface flow systems planted with taro could decrease the nitrate and phosphate content of wastewater, as well as organic matter. Taro's ability to capture other chemicals in aqueous environments is well reported in the literature. Taro has also been identified as a novel plant for the

application of phytoremediation and has been reported in the international literature as a hyperaccumulator of heavy metals (Pramar *et al*., 2012). Koshiba *et al*. (2013) studied the filtering effects of cultivated taro fields, which are natural wetlands used to grow taro, which can trap 90% of sediments.

Koshiba *et al*. (2013) documents the sediment trapping capacity of taro fields in Pelau over a four-month period. These fields mitigated the negative impacts of soil runoff on coral reefs using methods of growing taro that was used for many generations. Kako'o'oiwi (http://kakoooiwi.org/) is an organisation in Hawai'i with the aim to restore the cultural connection between the land and the people, and is working to restore agricultural and ecological productivity to wetlands of He'eia, in O'ahu. One objective of the organisation is to plant 45 acres of (mostly) taro within the wetlands and to return the land to its agricultural heritage; a form of agricultural restoration. The land will provide natural resources, ecosystems services, habitats for native birds, and help to absorb flood pulses, as well as cleaning the water, and providing jobs. The process involves removal of acres of exotic mangroves that are clogging the system. The project has considerable international interest.

Constructed wetlands in New Zealand could be functional rather than just aesthetically appealing. A cropping system essentially removes excess nitrogen from the system and taro should be considered.

Terracing can slow runoff and reduce soil erosion on dry land. Terraced planting traps sediment after a landslide. This avoids the successional planting, with small ferns followed by grasses, and other plants in the natural system. Taro planted on stream banks has been observed in Hawai'i, although Handy and Handy (1972) reported that planting taro on stream banks was not common, traditionally. Taro provides another option for riparian planting.

Perceptions: Taro is not indigenous

In Hawai'i and New Zealand, taro is not a native plant, or indigenous in a biological sense, but is certainly indigenous in a cultural sense. One big difference however, is that *kalo* is considered an ancestor by Hawaiians but not by Maori so has a much greater whakapapa significance. In discussions of the wider potential of growing taro in Waikato steams and waterways, opposition to growing taro in waterways include perceptions that it is not native and indigenous –it was first brought to Aoetearoa by the earliest settlors, but so was the kiori-pacific rat that wiped out many species (tuatara, native frogs, snipe-rails, etc.) on the mainland!

Further experiments need to be conducted to find the best taro variants to grow in streams, including the potential of the original taro cultivars to New Zealand, generally considered to be not very palatable. Preliminary results show that variant GP plants (with green petioles and pointed blades) grown in a stream were able to produce extremely large roots and few new tubers. There have been strong cultural perceptions observed of which taro should be grown in New Zealand streams and waterways. Some culturally and ecologically motivated people have encouraged the use of only locally-present varieties of taro for environmental remediation. These studies should be seen as part of a revival of interest in a historically important part of New Zealand's Polynesian-introduced flora.

However, people, including some *tangata whenua* acknowledge that taro is not strictly native to New Zealand and all varieties (Maori and Pacifika) may support common goals of sustainability. Further controlled studies are also merited on instream sediment control and the potential stream-blocking of instream taro planting.

Varieties/Cultivars

In Hawai'i, there are about 80 traditional or heritage varieties that are grown and these are all well described (Whitney *et al*., 1939). Some of these varieties are grown for their roots and some for leaf production. Some taro can withstand flood events, some can't. Some may be grown in cooler areas, some may not. Some may be grown in aquaponics for leaves, some may not survive in an aquaponics environment. Some do well in brackish/salty water, some do not. Some varieties may be eaten raw and free of calcium oxalate crystals and some may need a lot of cooking to remove acridity. Newer varieties are bred for example to be blight resistant and others for their amenity value. With taro becoming a gourmet food, one also need to also look at all varieties, and new ways of cooking, too. Some taro are good for making *poi* and some are not. It is generally considered that it is not the way you make *poi*—it is the way you grow it.

There is much in the literature about growing varieties of taro that do well in cooler temperate climates. However, the preference may be to trial Pacific Island taro, which is more familiar and marketable.

Cooking methods/taste

Taro leaf dishes such as *palusami* are traditionally made wrapped in banana leaves and baked (in an earth oven). Modern cooking methods are often used (e.g. pressure cookers, air fryers, modern ovens) with tin foil often used to wrap the food parcel. Tin foil however is reflective and does not allow heat to pass easily through the wrapped parcels. Banana plantations are being developed in commercial quantities in Northland and the East Coast of New Zealand and with some good results. There should be an ample supply of banana leaves, currently fed to cows, for preparing taro dishes, in larger quantities, and in a more traditional way.

Bussell and Triggs (2010) recommend further study on how to best optimise year-round production of young taro leaves in northern New Zealand. Our observations with a Pacific Island variety suggest that 'youngish' taro leaves from leaves grown out of the months of active growth may in fact have a slight bitter taste. This has yet to be investigated, and it may have to be a choice between making the most of the summer flush of taro leaves and trying to produce leaves throughout the year but of lower grade.

Conclusions

Growing taro in New Zealand should be seen as part of a revival of interest in a historically important part of New Zealand's Polynesian-introduced flora.

This paper outlines the potential benefits of comparing production methods in Hawai'i and New Zealand. Polynesian traditional methods of growing wetland taro in Hawai'i could be a useful method of trialling growing taro in New Zealand near and around streams, or where there is running water where the plant has the further ability to withstand the adverse effects of

frosts in ‘weed free’ conditions. This wetland scoping study adds relevance in the light of archaeological work that suggests traditional large-scale wetland production of taro in Northland. Some of these practices need to be trialled and implemented. However, a number of general and specific issues need to be raised at the outset and this paper discusses some of these issues/problems with possible solutions. Additional potential environmental benefits of growing taro in New Zealand could include reducing excess nutrient runoff, mitigating sediment loss, and phytoremediation.

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