In *Natural fibres in Australasia: Proceedings of the combined (NZ and AUS) conference of The Textile Institute, Dunedin 15-17 April 2009*, Edited by Wilson, C. A. and Laing, R. M. p121-125. Dunedin, New Zealand: The Textile Institute (NZ). ISBN: 978-0-9598019-3-4

Identifying harakeke (Phormium tenax) cultivars using whītau and fibre aggregate properties

B. Lowe[1], D. J. Carr[1], R. E. McCallum[2], T. Myers[3], B.E. Niven[1], R. Cameron[1], A. Gorham[4], C. Holtham[4], and K. Te Kanawa[1]

[1]*University of Otago, PO Box 56, Dunedin, New Zealand*
[2]*Ruaimoko Productions and Consultancy Ltd, PO Box 1388, Dunedin, New Zealand*
[3]*Dunedin Botanic Garden, Dunedin, New Zealand*
[4]*Kaimahi Harakeke, c/o B. Lowe, University of Otago, PO Box 56, Dunedin, New Zealand*
bronwyn.lowe@otago.ac.nz

Abstract. Harakeke (*Phormium tenax*) is a monocotyledonous plant endemic to Aotearoa (New Zealand) and Norfolk Island. Harakeke is an icon of contemporary New Zealand culture with the status of taonga (treasure) under Article II of the Treaty of Waitangi and the Ngāi Tahu Claims Settlement Act 1998. Māori have a long history of utilising whenu (strips of harakeke leaf) and whītau (fibre aggregates processed from harakeke leaf) to manufacture objects required for daily life e.g. ropes, nets, sails, containers, furnishings, clothing and artwork, both traditional and contemporary. Although there are only two species of *Phormium* (*P. tenax, P. cookianum*), Māori weavers recognise more than 60 different cultivars. Experienced weavers recognise different cultivars by assessing the appearance of the harakeke bush and leaf, and the behaviour and feel of the whenu and whītau as they are prepared for use.

Recent studies have attempted to characterise differences among harakeke cultivars recognised by weavers, by investigating properties of leaf and fibre collected from the cultivars. These studies have either investigated the properties of leaf and fibre using materials or textile science techniques, or else worked with weavers to carry out ethnobotanical assessments. In the work reported here, we have combined both approaches in order to discriminate between cultivars. Qualitative assessments of fibre properties by weavers have been compared with quantitative assessments provided by tensile testing. The work aims to contribute to both Mātauranga Māori (Māori knowledge) and textile science, by exploring the common ground between the two knowledge paradigms. The scope and relevance of this approach is discussed. The work reported also aims to provide information that will contribute to a broader study investigating the provenance and whakapapa (lineage) of a collection of harakeke cultivars growing in the Dunedin Botanic Garden.

Keywords: qualitative assessment, tenacity, extension

1. Introduction

Harakeke (*Phormium tenax*) is a monocotyledonous plant endemic to Aotearoa (New Zealand) and Norfolk Island, renowned for the whītau (fibre aggregate) that can be extracted from its leaves. It is an icon of contemporary New Zealand culture with the status of taonga (treasure) under Article II of the Treaty of Waitangi and Ngāi Tahu Claims Settlement Act 1998. There is enormous variation in harakeke, in part due to natural variation within the species (Cross 1912; Wehi and Clarkson 2007) and hybridisation with *Phormium cookianum* (Houliston, Heenan, and Smissen 2008) and in part due to a long history of selection of cultivars for whatu and raranga (traditional weaving), industrial fibre and horticultural purposes (Heenan 1991).

In the past, oral traditions ensured that unique weaving cultivars could be identified. Over time, many of these cultivars have been lost, and names that were recorded are no longer connected with plants found growing today. In some cases, oral tradition has however survived. An important example is a collection of 50 named cultivars, known as the Rene Orchiston Collection, now found growing under the kaitiakitanga (stewardship) of Manaaki Whenua (Landcare Research) at Lincoln in the South Island of New Zealand. The Rene Orchiston Collection includes traditional weaving cultivars from the North Island of New Zealand, most of them of known provenance. A catalogue of detailed descriptions of growth form, leaf and fibre characteristics and weaving suitability enables each of these cultivars to be identified (Scheele 2005).

Scientific assessments of whītau properties can assist with identifying differences among cultivars. Differences in whītau characteristics among 12 cultivars from the Rene Orchiston Collection and the effects of different growing conditions on those characteristics have been investigated using qualitative assessments by experienced weavers (Harris et al. 2008). The assessments clearly identified cultivars described in the Rene Orchiston catalogue as having easily stripped fibre. Assessments of ease of stripping and fibre breakage over all the cultivars tested were also in agreement with the catalogued descriptions. In another study, the mechanical properties of whītau were measured for 11 Rene Orchiston cultivars and a general agreement was found between the measured tenacity and the catalogued descriptions of their strength (Harris and Woodcock-Sharp 2000).

The Dunedin Botanic Garden, in the South Island of New Zealand, has a collection of harakeke that has been growing in the Garden for almost 100 years (Tannock 1909, 1910; Dunlop 2003). Unlike the Rene Orchiston collection, very little information is recorded about growth form, leaf and fibre characteristics and weaving suitability of these plants (Scheele 1997). Their provenance is not known, and none of them are named. It is not even clear how many unique cultivars are growing in the collection.

The aim of the work reported here was to assess the scope for using qualitative and quantitative assessments of whītau properties to characterise and discriminate between the harakeke cultivars in the Dunedin Botanic Garden.

2. Methods

A sample qualitative assessment form for describing whītau properties (Scheele 2007; Harris et al. 2008) was discussed amongst our group and modified to include assessments thought to best characterise the whītau extracted from a bush. Attributes agreed were: scoring on a scale of 0-100 ease of stripping whītau from the leaf, ease of removing para (non-fibrous leaf tissue) from the whītau, and the strength and fineness of the whītau; dichotomous scoring (yes/no) of whether whītau could be extracted from the full leaf length, whether it broke during extraction, and whether it separated; selection of descriptive terms for the whītau from a list; and comments on colour and overall characteristics.

Members of our group who are experienced with selecting and processing harakeke leaf for weaving (Cameron, Gorham, Holtham, McCallum and Te Kanawa) selected 23 harakeke bushes of interest from the 211 bushes in the Dunedin Botanic Garden collection. Four fans were selected from each bush and leaves harvested according to tikanga (correct procedure, lore). The rito and awhi rito (youngest leaf and first pair of leaves within a fan) were not harvested, whilst the remaining leaves were cut from the base of the fan with a knife, thus "cleaning" the fan. The fourth leaf was retained for whītau assessment. The remaining leaves were either used for raranga assessment (not reported here), passed on to weavers for use, or were disposed of according to Dunedin Botanic Garden protocol for pruning disposal.

Four weavers in our group prepared and assessed whītau from the fourth leaf of one fan each from each bush. Not all bushes were assessed by all weavers. Each leaf was split into even width strips and whītau extracted using the hāro technique (Te Kanawa 1992). The whītau from each strip was bundled separately and labelled with the position of the strip relative to the keel (inner, mid, outer). Whītau from each leaf was placed in separate paper bags and within 3 hours placed in standard conditions (20 ± 2°C and 65 ± 2% R.H.) (International Organisation for Standardisation, 2005). The qualities of the whītau were recorded on the assessment forms as each leaf was processed.

Whītau strength scores were then used to select a sub-set of four bushes assessed by all four weavers for further analysis. The four bushes were selected to represent the full 0-100 strength range.

Whītau from the four selected bushes was then prepared for tensile testing. To control for differences in whītau properties across the leaf (Harris and Woodcock-Sharp 2000; Carr et al. 2005), only whītau from the mid strips were used. Whītau was separated by hand into individual fibre aggregates. The mass (Mettler Toledo AT400 balance accuracy = 0.1mg) and length (Sands 1 m steel rule accuracy = 0.5 mm) of each fibre aggregate (n = 10) was measured and the linear density (tex) calculated. A bench-mounted 4464 Instron fitted with a 100-N lead cell (accuracy ± 0.5%) was used for tensile testing. Testing was completed in randomised blocks using a reference material (polyamide monofilament) at the beginning and end of each block. The gauge length (100mm) was located in the central portion of each specimen. Specimens were pre-loaded with a mass of 20g, tested at 10mm/min, the load-time response recorded by a Powerlab/16SP data acquisition system and chart for Windows v3.4.9 at a rate of 100 points per second (unfiltered), and tenacity (N/tex), and extension at maximum load calculated (Carr et al. 2005).

All attribute scores from qualitative assessments of whītau were ranked to investigate the consistency and reliability of the attribute in discriminating between the bushes. Tenacity and extension at maximum load data were analysed by nested analyses of variance (ANOVA) using SPSS version 16 software (SPSS Inc 2007). Prior to analysis, all data were checked for outliers, normality and homogeneity of variances. Whītau length data were not homogeneous and transformation did not achieve homogeneity of variances. Data were therefore analysed without transformation, and results should be treated with caution.

3. Results

It was clear from overall comments (summarised in Table 1) that there were at least three different types of cultivar in the group of 4 we assessed. C2 was clearly not suitable for whītau, F1 showed variation in whītau quality and B3 and B5 were both very suitable whītau plants. The ability to qualitatively discriminate these

TABLE 1. Overall comments of assessors regarding suitability of cultivar for extracting whītau

Cultivar	Overall description
C2	Not good for whītau, best suited to raranga
F1	Variable whītau quality, better suited to raranga
B3	Good to very good whītau
B5	Good to very good whītau

TABLE 2. Dichotomous (yes/no) assessments of whītau attributes

Attribute	No, all 4 leaves	Yes, all 4 leaves	Score varied
Whītau extracted from whole length	C2	B3, B5	F1
Whītau breaking	B3, B5		F1, C2
Whītau separating		B3, B5	F1, C2

TABLE 3. Cultivar ranking by assessors relative to average scores (cultivar code (no. of leaves within rank))

Attribute	Lowest rank 1	2	3	Highest rank 4
Ease of stripping whītau	C2 (2)	F1 (2)	B3 (2)	B5 (3)
Ease of removing para	C2 (4)	F1 (4)	B3 (3)	B5 (3)
Strength of whītau	C2 (4)	F1 (3)	B3 (3)	B5 (4)
Fineness of whītau	B3 (2), F1 (3)		C2 (1)	B5 (1)

three groups varied among the individual attributes assessed. Whītau extraction length appears to separate C2 from B3 and B5, while B3 and B5 are characterised by consistent extraction of whītau from the whole leaf length without breaking, and separation of whītau when it is extracted (Table 2). The attributes that showed the most consistent order of ranking by the assessors amongst the cultivars were ease of para removal and whītau strength (Table 3). Ease of para removal appears to separate C2 and F1, with overlap between B3 and B5. Whītau strength was ranked lowest for C2 and highest for B5, with overlap between F1 and B3.

Quantitative measures of fibre aggregate properties determined for cultivars F1, B3 and B5 are summarised in Table 4. Whītau extracted from cultivar C2 broke easily as it was extracted, and samples collected were too short (less than 250mm) to be tested. The mean extension at maximum load varied among the cultivars ($F_{2,9}$= 4.53, p = 0.04), from 2.16% for cultivar F1 to 2.79% for cultivar B5. Tukey analysis identified two groups, with cultivars B3 and B5 having greater extension to maximum load than cultivar F1. The mean length, linear density, and tenacity did not vary among the cultivars ($F_{2,9}$= 1.78, p = 0.22; $F_{2,9}$= 0.30, p = 0.75; $F_{2,9}$= 1.92, p = 0.20 respectively).

All fibre aggregate properties varied among leaves within each cultivar (length $F_{9,108}$= 12.58, p = 0.00; linear density $F_{9,108}$= 2.09, p = 0.04; tenacity $F_{9,108}$= 1.86, p = 0.07; extension at maximum load $F_{9,108}$= 2.874, p = 0.00).

TABLE 4. Whītau physical and mechanical property data (n=40; mean (s.d.))

cultivar	length (mm)	linear density (tex)	tenacity (N/tex)	extension at maximum load (%)
F1	660 (168)	17 (6)	0.465 (0.160)	2.38 (0.62)
B3	752 (129)	16 (7)	0.524 (0.174)	2.78 (0.73)
B5	803 (91)	18 (8)	0.559 (0.155)	2.79 (0.66)

4. Discussion

Simultaneous assessment of whītau properties by qualitative and textile science methods enabled some distinct cultivars to be identified, and resulted in similar ranking and grouping of the cultivars tested. Over the range of whītau properties assessed, both methods appeared to have a similar capacity to discriminate between cultivars. The most consistent rankings among the assessors clearly identified cultivar F1 as different to cultivars B3 and B5, but did not discriminate clearly between B3 and B5. Significant differences among cultivars for extension at maximum load showed a similar pattern. General agreement between quantitative and qualitative assessment of whītau quality has been noted by others (Harris and Woodcock-Sharp 2000; Carr et al. 2005), as has agreement between different kinds of qualitative assessment (Harris et al. 2008). However, these studies did not simultaneously apply and compare the different assessment methods, and were also working with known cultivars.

The results from our study suggest the range of mechanical properties that can be used to successfully discriminate between cultivars may be limited. Whītau extracted from the cultivar ranked as weakest in the qualitative assessment (C2) was too short to be tested. Measurement of mechanical properties may therefore be restricted to those cultivars characterised by stronger whītau. We also found that extension to maximum load was the only property to differ significantly among the cultivars we did test. Carr et al. (2005) had a similar finding when comparing the mechanical properties of cultivars all described as having "excellent fibre", whilst Harris and Woodcock-Sharp (2000) found "marked" differences for both breaking strength and extension at peak load among 11 cultivars representing a range from "weak" to "strong" fibre. Extension may be the most useful mechanical property for discriminating between cultivars with high quality whītau.

Qualitative assessments included a greater range of whītau attributes than that measured through tensile testing, and thus have the potential to provide clearer discrimination between cultivars. Our study has shown that the attributes, language and scoring systems used in the qualitative assessments could be improved. For example, attributes such as ease of para removal and strength of whītau provided consistent ranking across assessors, whilst fineness did not assist with identifying differences between cultivars. Other attributes, such as breakage and separation of whītau may have provided better discrimination between cultivars if scored on a scale rather than as a yes/no dichotomy. In sensory analysis of textiles, the language and scaling of scoring systems are usually developed through a series of sessions with a judging panel (Kawabata 1975; Ellis and Garnsworthy 1980; Philippe et al. 2004). Although we discussed the qualitative assessment forms used, we did not have the opportunity to develop the assessments through a number of iterations. As a result some attributes gave ambiguous results. We also did not have the opportunity to explore and modify the scoring of attributes that may have related most closely to the measured mechanical properties. Discrimination among cultivars using quantitative measures could be improved by including a greater range of measured attributes, such as modulus and toughness from tensile testing.

A desirable improvement to the methods we trialled would be reducing the time and leaf material required to assess the cultivars. One aspect of the tikanga of working with harakeke is that leaf is not harvested wastefully. Scientific measurement of properties on the other hand requires adequate replication, which may result in undesirable waste. A method for identifying cultivars that may meet both tikanga and scientific requirements could include a tiered process of assessment[1]. Experienced weavers can easily and consistently group cultivars on the basis of major differences using minimum leaf material (e.g. kete vs. whītau and overall whītau quality, as in Table 1). A targeted set of attributes could then be used to discriminate among cultivars within these groups. General comments such as those recorded in our study could be used to define and score additional attributes relevant within a group. For example, cultivars B3 and B5 were very similar across our attributes, and a comment was recorded that "these may be the same cultivar". However, another comment was recorded that "the fibre comes away when hapine" (hapine – remove moisture from and soften whenu) for B5, whilst a similar comment was not made regarding B3. An attribute scoring the degree of fraying during hapine may assist with discriminating among cultivars within a group characterised by high strength whītau.

5. Conclusions

The properties of whītau extracted from four harakeke cultivars growing at the Dunedin Botanic Garden were assessed qualitatively by experienced weavers and quantitatively by the measurement of tensile properties in order to identify different cultivars. Both methods of assessment gave similar ranking and grouping of the cultivars tested. Qualitative assessments

[1] Paper in preparation for submission to Ethnobotany Research and Applications.

provide greater scope for discriminating among cultivars than measures of tenacity and extension, because of the greater range of attributes measured. There is scope to improve the ability to discriminate among cultivars by refining the qualitative attributes measured, and including a greater range of quantitative measures.

6. Acknowledgements

This project is funded by the New Zealand Foundation for Research, Science and Technology, agreement number UOOX0605. We acknowledge the Treaty of Waitangi, the Ngāi Tahu Settlement Act 1998, the Convention on Biological Diversity, and the Mataatua Declaration on Cultural and Intellectual Property Rights of Indigenous Peoples. We also acknowledge the Kaimahi Harakeke, the Dunedin Botanic Garden and the University of Otago.

7. References

Carr, D J, N M Cruthers, R M Laing, and B E Niven. 2005. Fibre from three cultivars of New Zealand flax (*Phormium tenax*). *Textile Research Journal* 75 (2):93-98.

Cross, B D. 1912. Investigations on Phormium with regard to the improvement of its economic importance. MA, Canterbury College, University of New Zealand, Christchurch.

Dunlop, Eric. 2003. *The story of the Dunedin Botanic Garden. New Zealand's first*. Dunedin: Friends of the Dunedin Botanic Garden Inc.

Ellis, B. C., and R. K. Garnsworthy. 1980. A Review of Techniques for the Assessment of Hand. *Textile Research Journal* 50 (4):231-238.

Harris, W, and M T U A Woodcock-Sharp. 2000. Extraction, content, strength and extension of Phormium variety fibres prepared for traditional Maori weaving. *New Zealand Journal of Botany* 38:469-487.

Harris, W., S. M. Scheele, G. J. Forrester, K. T. Kanawa, M. Murray, and E. Pahewa. 2008. Varietal differences and environmental effects on fibre extracted from Phormium leaves and prepared for traditional Maori weaving. *New Zealand Journal of Botany* 46 (4):401-423.

Heenan, P B. 1991. *Checklist of Phormium cultivars*. Lincoln: Royal New Zealand Botany Institute.

Houliston, G. J., P. B. Heenan, and R. D. Smissen. 2008. Experimental crosses in Phormium confirm the lack of intrinsic barriers to interspecific hybridisation and the fertility of putative wild hybrids. *New Zealand Journal of Botany* 46 (4):393-399.

International Organisation for Standardisation. *ISO 139: 2005 Textiles - Standard atmospheres for conditioning and testing*. 2005. Geneva: International Organisation for Standardisation.

Kawabata, S. 1975. The standardization and analysis of hand evaluation. *Textile Machinery Society of Japan*.

Philippe, F., L. Schacher, D. C. Adolphe, and C. Dacremont. 2004. Tactile feeling: Sensory analysis applied to textile goods. *Textile Research Journal* 74 (12):1066-1072.

Scheele, S. 1997. Dunedin Botanic Gardens harakeke collection. *He Kōrero Kōrari* 2 (January):3.

Scheele, S. 2005. *Harakeke The Rene Orchiston Collection*. 3 ed. Lincoln, Canterbury, New Zealand: Manaaki Whenua Press.

Scheele, S. 2007. Pers. comm. 29/08/07. Lincoln.

SPSS Inc. 2007. Statistical Package for Social Sciences, SPSS 10.0 for Mac, version 16.0.1. Chicago, Illinois, USA: SPSS Inc.

Tannock, D. 1909. Dunedin Botanic Garden Letterbook: Dunedin City Council Archives.

Tannock, D. 1910. Dunedin Botanic Garden Annual Report: Dunedin City Council Archives.

Te Kanawa, D. 1992. *Weaving a kakahu*. Wellington: Bridget Williams Books in association with Aotearoa Moananui a Kiwa Weavers.

Wehi, P. M., and B. D. Clarkson. 2007. Biological flora of New Zealand 10. Phormium tenax, harakeke, New Zealand flax. *New Zealand Journal of Botany* 45 (4):521-544.