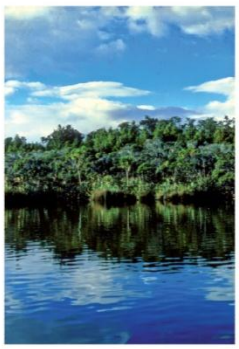

Fertility and ability to hybridise in two ‘eco-friendly’ dwarf cultivars of *Agapanthus* L’Hér. (Amaryllidaceae) in New Zealand

Landcare Research
Manaaki Whenua

Fertility and ability to hybridise in two ‘eco-friendly’ dwarf cultivars of *Agapanthus* L’Hér. (Amaryllidaceae) in New Zealand

Kerry Ford, Murray Dawson

Landcare Research

Prepared for:

Auckland Regional Council Biosecurity (Contract no. 0809/93/014)

21 Pitt Street
Private Bag 92-012
Auckland 1010
New Zealand

November 2010

Landcare Research, Gerald Street, PO Box 40, Lincoln 7640, New Zealand, Ph +64 3 321 9999, Fax +64 3 321 9998, www.landcareresearch.co.nz

Reviewed by:	*Approved for release by:*
Peter Heenan and Gary Houliston Researchers Landcare Research	Lynley Hayes
Landcare Research Contract Report:	LC 63

Disclaimer

This report has been prepared by Landcare Research for Auckland Regional Council Biosecurity. If used by other parties, no warranty or representation is given as to its accuracy and no liability is accepted for loss or damage arising directly or indirectly from reliance on the information in it.

Contents

Summary

Project and Client

- This report investigates the fecundity and ability of *Agapanthus* cultivars to hybridise with the tall-growing naturalised *A. praecox* subsp. *orientalis* and was completed by Landcare Research for Auckland Regional Council Biosecurity in November 2010.

Objective

- To investigate the sterility and low fertility claims made of the dwarf *Agapanthus* cultivars *A.* 'Finn' and *A.* 'Sarah' and test their ability to hybridise with the common tall-growing *A. praecox* subsp. *orientalis*.

Main Findings

- These fertility assessments (summarised in the Table overleaf) show that both dwarf cultivars are capable of producing germinable seed and cannot be described as sterile.
- However, the low fertility claims made of *Agapanthus* 'Finn' are justifiable and this cultivar is likely to have the least environmental impact of all material tested. *A.* 'Finn' was self-infertile and the seed yield in any outcross involving it, as the male or female parent, was never above 10%; pollen viability was also low at 40%. The low fertility of *A.* 'Finn' may be attributable to aneuploid reduction (missing chromosomes) or non-homologous chromosomes through hybridity, disrupting meiosis and therefore gamete formation.
- Although self-infertile, *Agapanthus* 'Sarah' has moderate fertility when outcrossed with *A. praecox* subsp. *orientalis* where it had a total seed yield of 22%. This is lower but approaching the seed set (39%) of crosses in the fertile dwarf *A.* 'Streamline'. Pollen viability of *A.* 'Sarah' was also high (85%).

Summary table of fertility assessments of dwarf cultivars of *Agapanthus* and accessions of *A. praecox* subsp. *orientalis*

	Male	**Female**		
	Pollen fertility	**Self fertility (seed set)**	**Cross fertility (seed set)**	**Cross fertility (seed germination)**
A. 'Finn'	Low (40%)	Nil	Low (7.4 %) As female parent: 9.7% As male parent: 5.8% (Very low when crossed with *A.* 'Streamline': 3.4%)	High (77%) As female parent: 74% As male parent: 80% (Moderate when crossed with *A.* 'Streamline': 52%)
A. 'Sarah'	High (85%)	Nil	Moderate (22%) As female parent: 5.9% As male parent: 36%	Very high (91.5%) As female parent: 65% As male parent: 100%
A. 'Streamline'	Very high (>95%)	Moderate (40%)	Moderate (39%) As female parent: 31.5% As male parent: 48%	Very high (96%) As female parent: 95% As male parent: 97%
Control Crosses between individuals of *A. praecox* subsp. *orientalis*	Very high (>95%)	Low (9.5%)	High 74% (sib-crosses)	Very high (100%)

Recommendations

- Using the benchmark results established by *A.* 'Finn', cultivars considered to be truly 'environmentally safe' should be self-sterile, have less than 10% cross fertility, and substantially reduced pollen viability.
- The methods employed here should be applied to objectively assess the fertility of other purportedly sterile or claimed low-fertility cultivars (e.g. *A.* 'Baby Pete', *A.* 'Double Diamond', *A.* 'Goldstrike', *A.* 'Pavlova', *A.* 'Peter Pan' and *A.* 'Tinkerbell'). These fertility assessments would create a list of genuine low-fertility *Agapanthus* cultivars that can be grown with the least chance of invasiveness.

1 Introduction

This report investigates the sterility and low fertility claims made of the dwarf *Agapanthus* cultivars *A.* 'Finn' and *A.* 'Sarah' and tests their ability or inability to hybridise with the common tall-growing *A. praecox* subsp. *orientalis*. It was completed by Landcare Research for Auckland Regional Council Biosecurity in November 2010.

2 Background

The widespread tall-growing and blue- (sometimes white-) flowered *Agapanthus* in New Zealand is known under the common names agapanthus, African lily and lily of the Nile. Its botanical name is currently referable to *A. praecox* subsp. *orientalis* (= *A. orientalis* in Healy & Edgar 1980). Although several species, subspecies and hybrids of *Agapanthus* are cultivated in New Zealand (Appendix 1–4), *A. praecox* subsp. *orientalis* is by far the most commonly cultivated in this country.

Its evergreen, perennial growth habit, showy flowers and long flowering season have made *A. praecox* subsp. *orientalis* popular for mass plantings in herbaceous borders and along driveways and roadside banks throughout cities and towns of New Zealand. It flourishes in a coastal, frost-free or lightly frosted temperate climate and is tolerant of a wide range of soil types and growing conditions – from dry exposed conditions to damp, lightly-shaded sites.

It was first cultivated in New Zealand from about the mid-1800s as an ornamental garden plant (e.g. *Lyttelton Times*, Vol. VI, Issue 332, January 5, 1856, p. 5; *Lyttelton Times*, Vol. VI, Issue 351, March 12, 1856, p. 6; *Wellington Independent*, Vol. XIX, Issue 2146, December 27, 1864, p. 3; *Marlborough Express*, Vol. XI, Issue 785, February 2, 1876, p. 6; *Otago Witness*, Issue 1364, January 19, 1878, p. 20; *Evening Post*, Vol. XIX, Issue 97, April 28, 1880, p. 4; *Otago Witness*, Issue 1657, August 25, 1883, p. 7; *Marlborough Express*, Vol. XXV, Issue 226, October 5, 1889, p. 3; *Otago Witness*, Issue 2082, January 18, 1894, p. 4; *Star*, Issue 5196, March 2, 1895, p. 7; Mason 1896; *The City Beautiful*, November 30, 1934, p. 6; *New Zealand Gardener*, August 1, 1947, p. 652).

Perceptions of *Agapanthus*

People have a marked love–hate relationship over *Agapanthus* and hold contradictory views.

On one hand the numerous cultivars are popular and widely available from the garden industry, both locally and internationally, and are exported commercially in large quantities. They are useful garden, container and amenity plants for year-round lush foliage, long flowering periods, hardiness and low maintenance.

However, on the other hand *Agapanthus praecox* subsp. *orientalis* is also considered a nuisance and a weed. It has serious impacts on native ecosystems, competing with and displacing native plant communities, particularly in coastal areas. Its rhizomes are extremely difficult to dig out and remove. It has some resistance to herbicides and there is no biocontrol available. Furthermore, *A. praecox* is among the National Poisons Centre's top 10 poisonous plants and regularly involved in childhood poisonings (Popay et al. 2010). *Agapanthus* species are suspected of causing haemolytic poisoning in humans, and the sap causes severe ulceration of the mouth. Sap and leaves are considered to have low to medium harm potential, and are also an irritant to the skin (www.landcareresearch.co.nz/publications/infosheets/poisonplants/poisplants_external.asp and www.biosecurity.govt.nz/files/pests/plants/nppa/nppa-tag-assessments.pdf).

Agapanthus praecox subsp. *orientalis* was first recorded as naturalised in New Zealand in 1952 (Neumann 1952; Healy 1958; Healy & Edgar 1980). Neumann (1952, p. 695) commented on 'masses of blue agapanthus' growing wild along roadsides at Hokianga. Healy (1958, p. 532) cited the first herbarium collections of naturalised plants – Allan Herbarium specimens made by Ruth Mason and Neville Moar in 1953 (CHR 81051, Westport, near Orowaiti Estuary; CHR 88610, Granity, Buller County; Appendix 4.2). Healy (1958) made his own observations of wild plants and in the *Flora of New Zealand* Vol. 3, Healy & Edgar (1980, p. 47–48) gave the localities as 'Occasional on coastal cliffs; rare and local on roadsides and in waste land' in Auckland City, Whakatane, near Westport, Lyttelton, near Oamaru, at Port Chalmers and Andersons Bay. Figure 1 shows the distribution based on herbarium records and Appendix 4 lists herbarium specimens.

In the 30 years since Vol. 3 of the *Flora of New Zealand* (Healy & Edgar 1980) was published, there has been increasing concern about the spread and invasiveness of *A. praecox* subsp. *orientalis*, particularly in the Auckland Region (e.g. Popay et al. 2010). In that region, it is a particular problem on the steep coastal cliffs at Piha, Anawhata and Karekare (ARC 2005); it has also been found on Rangitoto Island, Whangamata Beach (Zimer 2008) and Opito Bay on the Coromandel Peninsula (Figure 2). It produces abundant seed that is dispersed by wind and water and can also spread by vigorous rhizomatous growth eventually forming a dense and robust monoculture. It now threatens remnant indigenous ecosystems, particularly cliffs, riparian strips, duneland and forest margins of coastal areas.

To address these concerns and after a year's consultation (Thompson 2006; Williams & Thompson 2006), the decision was made in 2007 to include the typical large growing form of *A. praecox* subsp. *orientalis* in the Auckland Regional Pest Strategy as a Surveillance Pest Plant (ARC 2007–2012); on 1 July 2008 it was prohibited from sale, propagation, distribution and exhibition (large forms only) in the Auckland Region. In 2008 *A. praecox* was added to the consolidated list of environmental weeds in New Zealand (Howell 2008).

In a response to demands from the public to have *Agapanthus* selections they can still buy and grow, and from local authorities for less invasive alternatives, the New Zealand nursery industry have produced and marketed 'eco-friendly' (claimed to be sterile or of low-fertility) and dwarf (low-growing) cultivars.

Claims of sterility are rather anecdotal and had not been substantiated by underpinning research. This report documents our studies of two dwarf cultivars said to be eco-friendly, *A.* 'Finn' (Figure 3) and *A.* 'Sarah' (Figure 4).

3 Objectives

1. Assess levels of fertility and infertility (fecundity) of *Agapanthus* 'Finn' and *A.* 'Sarah'
2. Elucidate the causes of any infertility encountered
3. Test whether *A.* 'Finn' and *A.* 'Sarah' can produce viable seed when crossed with the common tall-growing *A. praecox* subsp. *orientalis* and a known fertile dwarf cultivar (*A.* 'Streamline')

This information should help to provide objective criteria and methodologies to enable the selection of cultivars that will be less invasive in New Zealand's natural environment than the naturalised *A. praecox* subsp. *orientalis.*

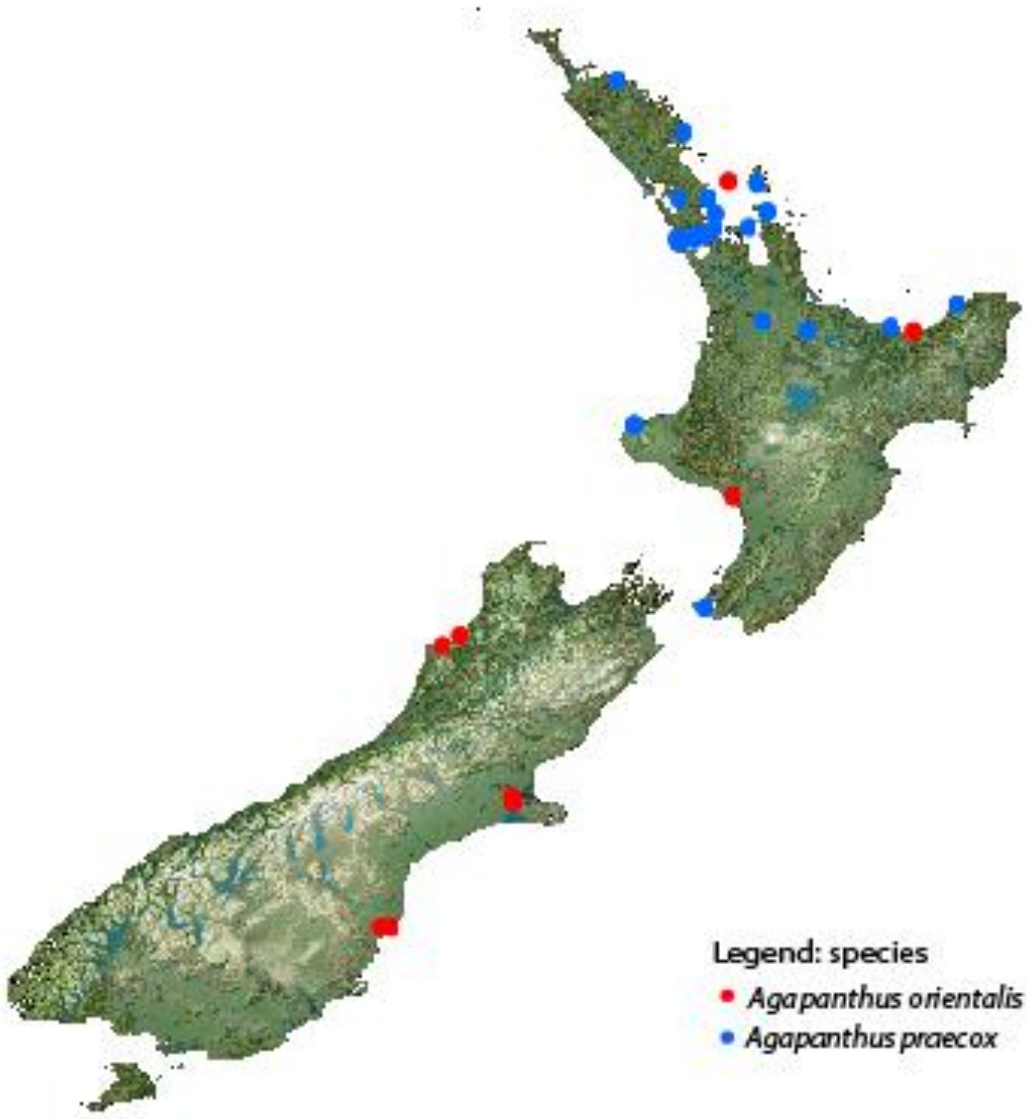

Figure 1 Distribution map of *Agapanthus praecox* subsp. *orientalis* (under its various names) in New Zealand from herbarium records (generated from the New Zealand Virtual Herbarium, www.virtualherbarium.org.nz). It is also locally established on Chatham (Rekohu) Island (AK 295928–295929).

Figure 2 Blue- and white-flowered *Agapanthus praecox* subsp. *orientalis* naturalised at Opito Bay on the Coromandel Peninsula. **A.** Population. **B.** Clumps of white- and blue-flowered plants. Photos: Trevor James

Figure 3 *Agapanthus* 'Finn': **A.** plant, **B.** inflorescence, **C.** flower. Photos: Kerry Ford

Figure 4 *Agapanthus* 'Sarah': **A.** plant, **B.** inflorescence, **C.** flower. Photos: Kerry Ford

Figure 5 *Agapanthus* 'Streamline': **A.** plant, **B.** inflorescence, **C.** flower. Photos: Kerry Ford

4 Materials and methods

To assess levels of fecundity (fertility and infertility) in our study group, we undertook pollen viability counts, pollen growth observations, sib-, self- and reciprocal crossing experiments, seed set and seed germination counts.

4.1 Plant material

Material for this study was obtained from plant nurseries (for the cultivars) and established plantings and naturalised populations (for *A. praecox* subsp. *orientalis*). All plants were grown on at the Landcare Research experimental gardens at Lincoln. Details of accessions and cultivars used are listed in Appendix 4.1.

Three dwarf cultivars were selected for this study. *A.* 'Finn' (Figure 3) and *A.* 'Sarah' (Figure 4) were chosen for their claimed sterility or low-fertility. The third dwarf *Agapanthus*, *A.* 'Streamline' (Figure 5), was chosen because it was known to be a fertile, long-flowering cultivar that is commonly available and widely cultivated in New Zealand.

We collected several accessions of the taller growing *A. praecox* subsp. *orientalis* from long-established plantings and naturalised sites in Christchurch City and from Banks Peninsula, Canterbury. These plants set abundant seed and are obviously highly fertile.

4.2 Pollen staining

Pollen stainability of the *Agapanthus* cultivars and accessions was determined by tapping anthers from recently opened flowers out on to a microscope slide with a drop of Alexander's differential stain (Alexander 1980). Normal pollen grains (non-aborted, presumed viable) stain dark red whereas aborted (inviable) grains stain light green. For *A.* 'Finn' and *A.* 'Sarah', the percentage of 'viable' pollen was assessed by counting more than 350 grains per slide. For *A.* 'Streamline' and *A. praecox* subsp. *orientalis*, pollen 'viability' was obviously greater than 95% so we did not produce absolute counts. For each cultivar and several accessions of *A. praecox* subsp. *orientalis*, pollen stainability was examined on several different dates, on several different plants, and on several anthers from the same plant. Because the pollen counts were relatively similar for each, they were aggregated into a summary table.

4.3 Artificial crossing experiments

The plants used for these experiments were grown as potted plants isolated in separate shade-houses to avoid accidental cross-pollination. The plants were emasculated by using tweezers to remove stamens before each flower opened and then the flower was bagged with silk jewellery pockets with draw-strings, to prevent insect visits. In all crosses pollen from at least two different anthers from each male parent was used to pollinate any given flower.

As a control, seven sib-crossings were conducted amongst the *A. praecox* subsp. *orientalis* accessions to check that these plants were indeed interfertile and able to set seed.

Self-pollinations were also done for two of the accessions of *A. praecox* subsp. *orientalis* and each of the three dwarf cultivars to test for self-fertility.

Reciprocal crosses were made between dwarf cultivars (*A.* 'Finn'/*A.* 'Streamline') and between all cultivars and *A. praecox* subsp. *orientalis* (*A.* 'Finn'/*A. praecox*, *A.* 'Sarah'/*A. praecox*, *A.* 'Streamline'/*A. praecox*). Our reciprocal crossing plan is outlined in Table 1.

Table 1 Reciprocal crossing plan and number of crosses made between *Agapanthus* cultivars and *A. praecox* subsp. *orientalis*

	♂ *A.* 'Finn'	♂ *A.* 'Sarah'	♂ *A.* 'Streamline'	♂ *A. praecox*
♀ *A.* 'Finn'			11	44
♀ *A.* 'Sarah'				32
♀ *A.* 'Streamline'	12			35
♀ *A. praecox*	49	31	27	

Each individual flower that was pollinated was re-bagged to continue exclusion of pollinating insects. Dated and labelled tags were attached on each flower stalk. Seed capsules were collected when or if they reached maturity.

Percentage yield of seed was calculated by dividing the actual yield (number of seeds produced) by the total potential yield (number of ovules) in a capsule at maturity.

4.4 Germination of seed

A sampling of 10 seeds (where 10 were available) were collected and sown from each seed capsule arising from the sib-, self- and cross-pollinations. Plants were raised in a bark, peat, and sand potting mixture with Osmocote® slow-release fertiliser and grown on in a shaded cold-frame over winter.

4.5 Preparation of flowers for pollen tube growth observations using fluorescent microscopy

Fluorescent microscopy was used to directly observe pollen tube growth on the stigmas and down the styles of the flowers. Reciprocal crosses were made between dwarf cultivars *A.* 'Finn', *A.* 'Sarah' and *A.* 'Streamline' with several accessions of *A. praecox* subsp. *orientalis*. The flowers were left for set intervals after pollination (e.g. 4, 7, 12, 18, 24, 72 h) and then harvested. These set intervals were used to evaluate the optimal time to observe pollen tube growth; 12–24 h gave the best results and it is these observations recorded in Results. Plant pistils (ovary, stigmas and styles) were excised from each flower to assess pollen tube growth. Each ovary was split longitudinally in half to allow for penetration of reagents. Samples were fixed in acetic acid:ethanol (1:3) for 12–24 h. Fixative was then replaced with 50% ethanol for 30 min then samples were stored in 70% ethanol until further

processing for microscopic examination. Samples were transferred to 50% ethanol and distilled water for 30 min each to wash out residual fixative. To soften and clear tissue, samples were transferred to 8 M NaOH (sodium hydroxide) solution for several hours to overnight. Samples were washed three times in distilled water and transferred to decolourised aniline blue stain for 2 h to overnight. Samples were transferred briefly into distilled water to remove excess stain and mounted on microscope slides with 50% glycerol. Material was pressed flat with a coverslip for examination with an epifluorescent microscope (390–440 nm UV). These techniques are adapted from the procedures outlined in Kearns & Inouye (1993).

4.6 Flow cytometry

Flow cytometry was used to test for possible polyploidy, aneuploidy or hybrid origins of the plant material.

For flow cytometry, isolation of nuclei from leaf tissue followed the method of Doležel and Bartoš (2005). A fragment of fresh leaf tissue (c. 6 mm^2) was placed in a plastic Petri dish together with a similar amount of leaf from the reference species used as an internal standard (*Agave americana*). Leaf tissue was co-chopped in the presence of one drop of commercial nuclei isolation buffer, UV CyStain® UV Precise T solution A (100 ml deionised water, 2.1 g citric acid, 0.5 g Tween 20) using a fresh razor blade. When well chopped an additional 0.5 ml of solution A was added. After approximately 3 min the sample was filtered through a 30-µm filter, and 2.0 ml of Partec Cystain® UV Precise T solution B (100 ml deionised water, 7.9 g dibasic sodium phosphate, 0.5 ml DAPI stock) was added. Samples were analysed for DNA content after at least 3 min of staining. For this, the Partec PA-II Particle Analysing System (PAS) was employed, using filter combinations of UG 1, TK420, TK590, and GG435 and a mercury arc lamp (HBO 100 W/2). For each sample 5000 nuclei were measured. DNA was stained with DAPI, a non-intercalating dye that binds preferentially to A–T bases, and results cannot therefore be directly expressed in picograms (Johnston et al. 1999). The internal standard we used (*Agave americana*) was also used by Zonneveld and Duncan (2003) as an internal standard in their flow cytometric measurements of nuclear DNA content in *Agapanthus*.

5 Results

5.1 Observations of floral morphology

In the course of our experiments, we observed a few flower morphology features. A pollination droplet was commonly secreted on the capitate (knob-like) stigma of both *A. praecox* subsp. *orientalis* and *A.* 'Streamline' plants, signifying receptivity of the ovary (Figure 6A), but this was notably absent in both *A.* 'Finn' and *A.* 'Sarah'. Split styles and ovaries and deformed stigma were observed in *A.* 'Sarah' (Figure 6B) and all plants of this cultivar often had aberrant flowers within an inflorescence. The absence of a pollination droplet and aberrant flowers may be factors responsible for the low seed set in *A.* 'Finn' and *A.* 'Sarah' (see later).

Figure 6 Stigma and style observations in *Agapanthus*. **A.** Pollen drop on the stigma (arrowed) of *A.* 'Streamline'. **B.** Split styles (arrowed) typical in the flowers of *A.* 'Sarah'. Photos: Kerry Ford

5.2 Pollen staining

Agapanthus 'Finn' only had c. 40% stainable (presumed viable) pollen with the remainder of pollen grains aborted and inviable (Table 2; Figure 7A). In contrast, *A.* 'Sarah' had pollen stainability of 85%, indicative of relatively high viability. The pollen of *A.* 'Streamline' and *A. praecox* subsp. *orientalis* shared the highest stainability, more than 95%, implying high levels of pollen viability.

Of the stained ('viable') pollen grains, both *A.* 'Finn' and *A.* 'Sarah' were observed to have two different pollen sizes and this variation was more common in *A.* 'Sarah' (Figure 7B). Dimorphic pollen grains may suggest developmental abnormalities such as unreduced gametes.

Table 2 Pollen staining with Alexander's differential stain of *Agapanthus* cultivars and *A. praecox* subsp. *orientalis*

	Total no. of pollen grains / (no. of anthers)	Stained pollen	Unstained pollen	Percentage of stained pollen
A. 'Finn'	12 250 (26 anthers)	4874	7376	39.79%
A. 'Sarah'	887 (6 anthers)	754	133	85.01%
A. 'Streamline'	(3 anthers)			>95%
A. praecox	(6 anthers)			>95%

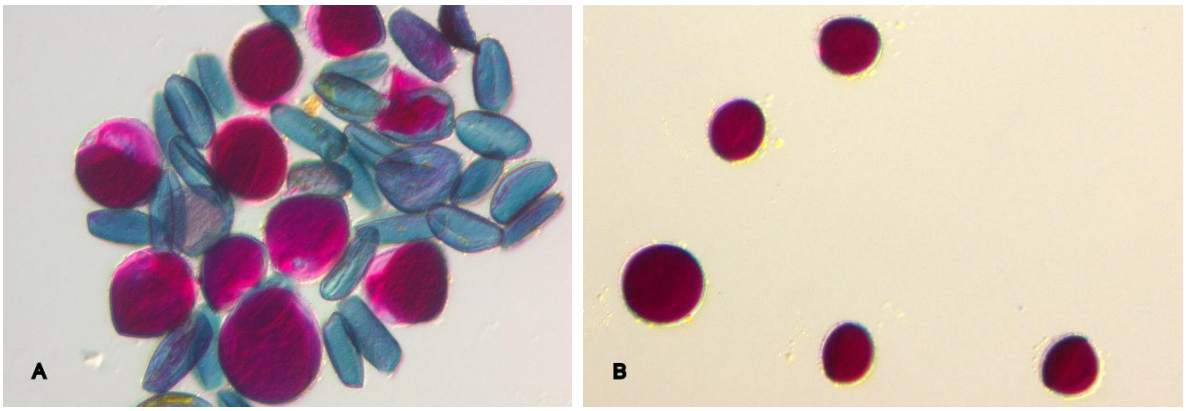

Figure 7 Pollen stainability of *Agapanthus* cultivars. **A.** *A.* 'Finn' showing empty aborted pollen grains in light blue and stained pollen in dark red. **B.** *A.* 'Sarah' showing pollen of different sizes. Photos: Kerry Ford

5.3 Artificial crossing experiments

The results from the seven control sib-crossings between the accessions of *A. praecox* subsp. *orientalis* (individuals collected around Christchurch and Banks Peninsula) show that they are all interfertile and set seed (Table 3). A total of 134 seeds were harvested from all of the plants. The total potential yield of seed was 180 (i.e. the total number of ovules) giving an average overall yield of 74% – the highest seed set in this study.

Table 3 Number of seeds and percentage yield from sib-crossings between accessions of *Agapanthus praecox* subsp. *orientalis*. Each result represents a single pollination from which the seeds were harvested out of each capsule. (A = Akaroa, D = Diamond Harbour, G = Governors Bay, C = Cashmere, P = Pitcher property, Avonhead – see Appendix 4.1)

	♂ *A. praecox*-A	♂ *A. praecox*-D	♂ *A. praecox*-G	♂ *A. praecox*-C	♂ *A. praecox*-P
♀ *A. praecox*-A					
♀ *A. praecox*-D	21 (87%)			17 (70%)	
♀ *A. praecox*-G	22 (91%)			13 (54%)	
♀ *A. praecox*-C	15 (62%)				
♀ *A. praecox*-P		17 (56%)		29 (96%)	

The deliberate self-pollinations of *A.* 'Finn' and *A.* 'Sarah' produced no seed suggesting that these cultivars are self-infertile (self-incompatible) (Table 4). In contrast, all five self-pollinated flowers of *A.* 'Streamline' produced seed (a total yield of 40%) indicating a moderate level of self-fertility. For *A. praecox* subsp. *orientalis*, two flowers (each from a different accession) out of the 10 that were self-pollinated produced seed (6 seeds from one flower and 17 from the other) – resulting in a relatively low yield of 9.5%.

Table 4 Self-pollinations of *Agapanthus* cultivars and *A. praecox* subsp. *orientalis*

	No. of flowers self-pollinated	Seed set	% yield of seeds
A. 'Finn'	21	0	0
A. 'Sarah'	5	0	0
A. 'Streamline'	5	5 fls set 49 seeds	40%
A. praecox	10	2 fls set 23 seeds	9.5%

All the crosses between the dwarf *Agapanthus* cultivars and *A. praecox* subsp. *orientalis* set at least some seed (Table 5). Slightly smaller but seed of normal appearance came from crosses where the dwarf *A.* 'Sarah' and *A.* 'Streamline' were the female parents (Figure 8). Crosses with *A.* 'Finn' as the female parent (♀ *A.* 'Finn' × ♂ *A. praecox* subsp. *orientalis* and ♀ *A.* 'Finn' × ♂ *A.* 'Streamline') produced seed that was considerably smaller and with an undeveloped dispersal wing, and distinctly lighter in colour (all of the seed that germinated grew into healthy plants – see Germination of seed).

The reciprocal crosses *A.* 'Finn'/*A.* 'Streamline' both set seed, but the yields were low, 2.0% and 4.5%. The reciprocal crosses *A.* 'Finn'/*A. praecox* subsp. *orientalis* also had low yields, of 9.7% and 5.8%.

There were marked differences according to the direction of the crosses between *A.* 'Sarah' and *A. praecox* subsp. *orientalis*. The cross ♀ *A.* 'Sarah' × ♂ *A. praecox* subsp. *orientalis* had a low seed yield of 5.9%, but its reciprocal cross ♀ *A. praecox* subsp. *orientalis* × ♂ *A.* 'Sarah' had a relatively high yield of 36%.

The reciprocal crosses between the fertile dwarf *Agapanthus* cultivar *A.* 'Streamline' and *A. praecox* subsp. *orientalis* set seed at moderate yields of 31.5% and 48%.

Table 5 Total number of seeds and percentage yield from reciprocal crosses made between *Agapanthus* cultivars and *A. praecox* subsp. *orientalis*

	♂ *A.* 'Finn'	♂ *A.* 'Sarah'	♂ *A.* 'Streamline'	♂ *A. praecox*
♀ *A.* 'Finn'			4 (2.0% yield)	77 (9.7% yield)
♀ *A.* 'Sarah'				46 (5.9% yield)
♀ *A.* 'Streamline'	13 (4.5% yield)			263 (31.5% yield)
♀ *A. praecox*	69 (5.8% yield)	311 (36.0% yield)	316 (48.0% yield)	

Figure 8 Seeds from artificial crosses. Female parents are named first. Photos: Kerry Ford

5.4 Germination of seed

All of the seeds sampled from sib-crossing the *A. praecox* subsp. *orientalis* accessions (Table 3) germinated and produced healthy plants.

Of 37 seeds sown from selfed *A.* 'Streamline', 22 germinated (59%). These grew into smaller and less vigorous plants compared with all other plants grown from seed in this experiment (e.g. Figure 9).

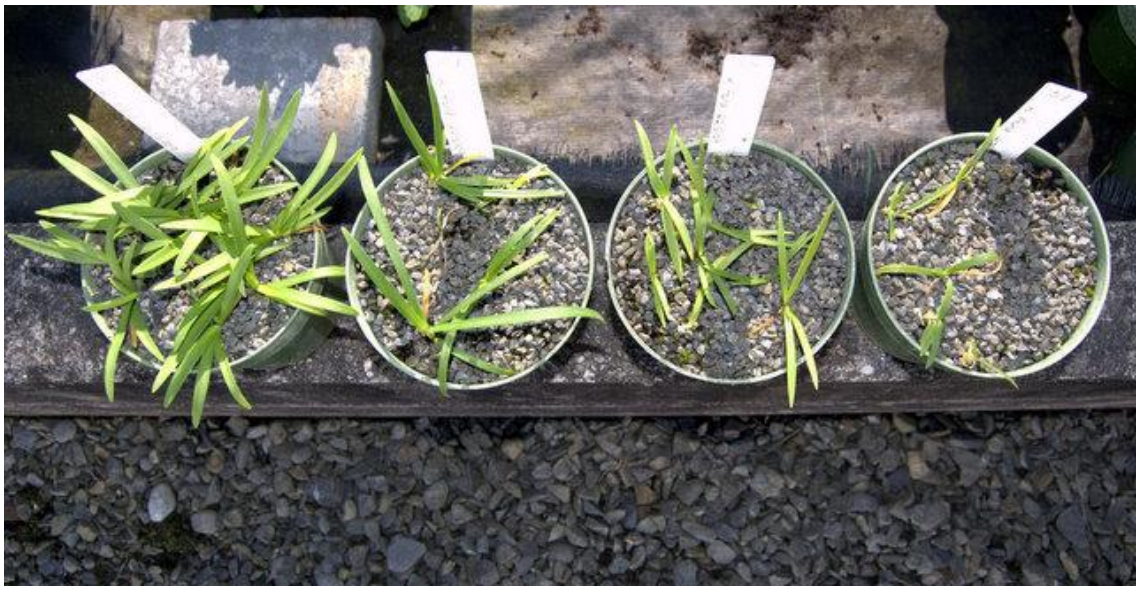

Figure 9 Control *Agapanthus praecox* subsp. *orientalis* seedlings (extreme left) next to three pots of seedlings arising from self-pollinating *A.* 'Streamline'. Photos: Kerry Ford

Of the total 472 seeds sown from the full set of crosses, 362 seeds (77%) germinated and grew into healthy robust plants.

The highest germination rate of all crosses was 100% for ♀ *A. praecox* subsp. *orientalis* × ♂ *A.* 'Sarah' (Table 6); the reciprocal crosses between *A. praecox* subsp. *orientalis* and *A.* 'Streamline' were also high (≥ 95%).

The percentage of seed germination from the reciprocal crosses between *A.* 'Finn' and *A. praecox* subsp. *orientalis* were similar to each other and relatively high in either direction (74% and 80%), as was the case for the crosses between *A.* 'Streamline' and *A. praecox* subsp. *orientalis* (95% and 97%) (Table 6).

In contrast, there was a marked difference in the percentage of seed germination depending on the direction of the crosses between *A.* 'Sarah' and *A. praecox* subsp. *orientalis* – 65% for ♀ *A.* 'Sarah' × ♂ *A. praecox* subsp. *orientalis* compared with 100% seed germination for the reciprocal cross. There were also differences according to the direction of cross in *A.* 'Finn' and *A.* 'Streamline' – 25% for ♀ *A.* 'Finn' × ♂ *A.* 'Streamline', and 61% for the reciprocal cross; these were the lowest germination rates in this study.

Table 6 Germination of seeds from crosses of *Agapanthus* cultivars with *A. praecox* subsp. *orientalis*. Results are expressed as number of seed germinated (left of the slash) / number of seed sown (right of the slash), and percent germination (in brackets)

	♂ *A.* 'Finn'	♂ *A.* 'Sarah'	♂ *A.* 'Streamline'	♂ *A. praecox*
♀ *A.* 'Finn'			1/4 (25%)	47/63 (74%)
♀ *A.* 'Sarah'				19/29 (65%)
♀ *A.* 'Streamline'	8/13 (61%)			76/80 (95%)
♀ *A. praecox*	40/50 (80%)	90/90 (100%)	82/84 (97%)	

5.5 Pollen tube growth observations using fluorescent microscopy

Where our pollinations resulted in pollen tube growth, the results were clearly observable (Figure 10).

The majority of sib-pollinations among the *A. praecox* subsp. *orientalis* accessions showed copious germination of pollen grains on the stigma and strong growth of pollen tubes down the styles (Table 7, Figure 10B–C).

Table 7 Pollen tube growth down styles as visualised with fluorescent microscopy

Cultivar and accession	Notes	Pollen tube growth		
		Strong growth	Weak growth	No growth
♀ *A.* 'Finn' × ♂ *A.* 'Finn'	Pollinations between two plants of the same cultivar	1	1	7
♀ *A.* 'Finn' × ♂ *A. praecox*	Reciprocal pollinations	5	0	5
♀ *A. praecox* × ♂ *A.* 'Finn'		0	0	10
♀ *A.* 'Sarah' × ♂ *A. praecox*	Reciprocal pollinations	1	4	8
♀ *A. praecox* × ♂ *A.* 'Sarah'		1	4	5
♀ *A.* 'Streamline' × ♂ *A. praecox*	Reciprocal pollinations	6	2	9
♀ *A. praecox* × ♂ *A.* 'Streamline'		6	0	14
♀ *A.* 'Finn' × ♂ *A.* 'Streamline'	Reciprocal pollinations	5	3	4
♀ *A.* 'Streamline' × ♂ *A.* 'Finn'		0	3	5
♀ *A. praecox* × ♂ *A. praecox*	Sib-pollinations	7	3	2
A. praecox	Self-pollinations	0	3	5

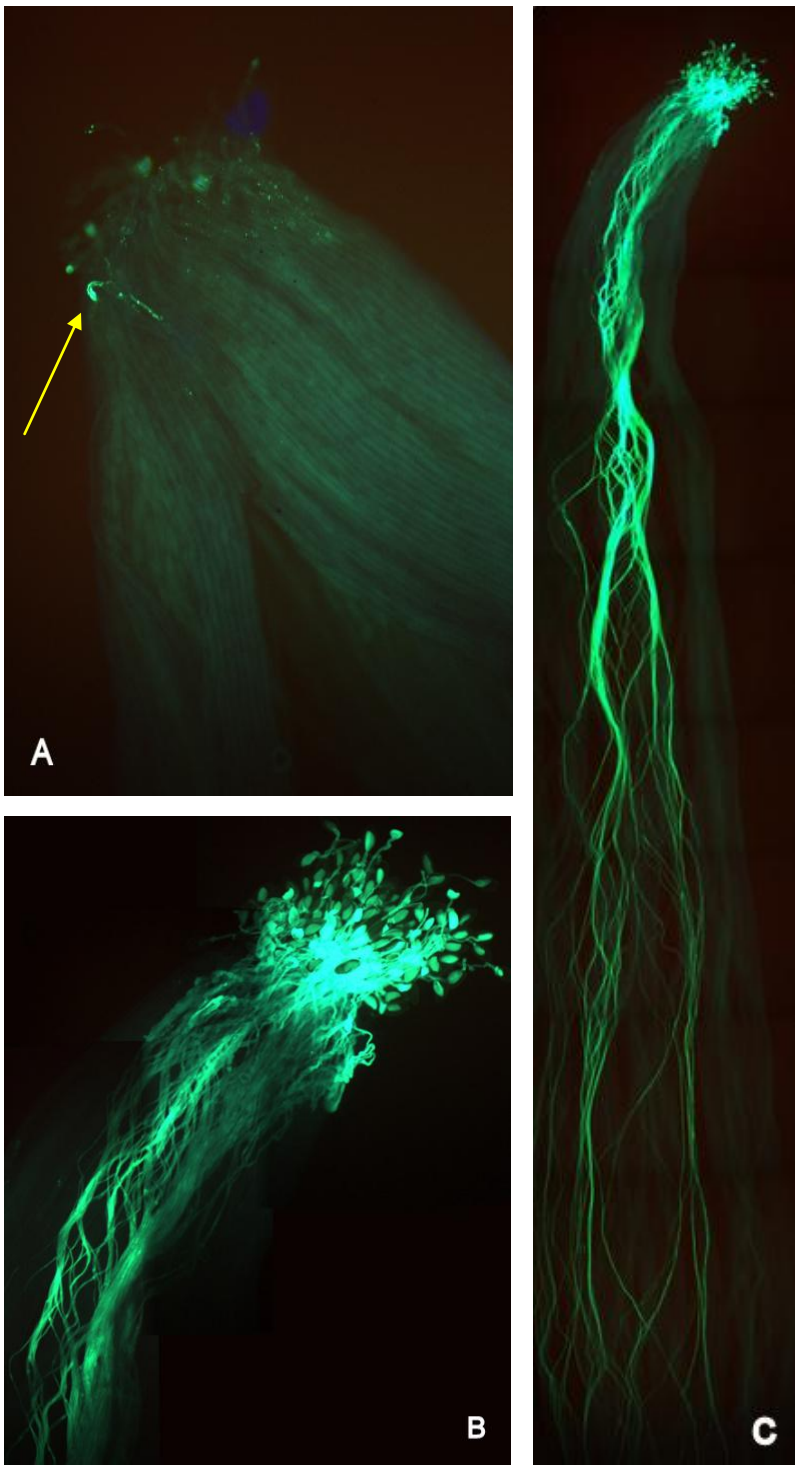

Figure 10 Pollen germination and pollen tube growth in *Agapanthus* stigmatic and stylar tissue viewed by fluorescent microscopy. **A.** Weak growth (arrowed) for ♀ *A. praecox* subsp. *orientalis* × ♂ *A.* 'Sarah'. **B–C.** Strong growth for a sib-cross among *A. praecox* subsp. *orientalis*. **C.** Pollen tube growth down nearly the full length (c. 30 mm) of the style of *A. praecox* subsp. *orientalis*. Photos: Murray Dawson

Conversely, for the self-pollinations of *A. praecox* subsp. *orientalis*, there was weak or no pollen germination or pollen-tube growth.

In self-pollinated *A.* 'Finn' (pollinations between two different plants of the same cultivar) the majority of pollinations resulted in no pollen grain germination on the stigma and no pollen-tube growth down the styles. We observed only a single pollen grain with strong pollen tube growth when self-pollinated. However, because we encountered no seed set (Table 4), fertilisation either failed or else any developing embryos aborted at an early stage in development.

Results varied somewhat for the reciprocal pollinations involving the cultivars. When *A.* 'Finn' was used as a pollen parent there was no germination or at best weak pollen tube growth. When *A.* 'Finn' was used as a female parent, there was about 50% pollen tube germination and growth.

The reciprocal pollinations between *A.* 'Streamline' and *A. praecox* subsp. *orientalis* were relatively consistent, showing similar proportions of pollen tube germination and growth.

The reciprocal pollinations between *A.* 'Sarah' and *A. praecox* subsp. *orientalis* were also relatively consistent but with lower pollen tube germination and growth (lower than reciprocal pollinations between *A.* 'Streamline' and *A. praecox* subsp. *orientalis*).

5.6 Flow cytometry

Agapanthus 'Finn' had a noticeably low ratio, 1.27, against the standard (*Agave americana*) suggesting the smallest amount of total DNA in the study group. This is also reflected in crosses involving *A.* 'Finn' with both *A.* 'Streamline' and *A. praecox* subsp. *orientalis*, where the ratio varies from 1.28 to 1.32 (Table 8).

Agapanthus 'Sarah' and *A.* 'Streamline' (and their hybrids with *A. praecox* subsp. *orientalis*) exhibit much the same ratio against the standard, suggesting that they have a similar total amount of DNA as *A. praecox* subsp. *orientalis*.

The control accessions of *A. praecox* subsp. *orientalis* show a relatively constant ratio against the standard (1.33−1.38) suggesting a similar DNA amount in all five *A. praecox* subsp. *orientalis* plants.

Table 8 Flow cytometry results. Low ratios, all involving *Agapanthus* 'Finn', are in bold. Each row represents a different plant or cross. (For accessions of *A. praecox* subsp. *orientalis*, A = Akaroa, D = Diamond Harbour, G = Governors Bay, C = Cashmere, P = Pitcher property, Avonhead – see Appendix 4.1)

	No.	Agave	Target	Ratio	cv1	cv2
Parent plants						
A. 'Finn'		69.61	88.42	**1.27**	4.59	4
A. 'Finn'		67.55	85.9	**1.27**	4.49	3.97
A. 'Sarah'		69.92	92.55	1.32	6	5.1
A. 'Sarah'		60.86	82.3	1.35	7.8	5.5
A. 'Streamline'		70.9	95.74	1.35	3.9	2.78
A. 'Streamline'		66.58	88.94	1.34	4.5	3.95
A. praecox-A	control	51.69	70.14	1.36	3.9	3.29
A. praecox-D	control	55.64	74.21	1.33	3.7	3.7
A. praecox-G	control	66.27	89.27	1.35	3	2.7
A. praecox-C	control	62.88	84.93	1.35	6.57	4.97
A. praecox-P	control	47.4	65.62	1.38	9.6	5.65
Seedlings of crosses						
A. 'Finn' × *A. praecox*-C	43	55.2	71.34	**1.29**	5.6	4
A. 'Finn' × *A. praecox*-C	44	57.58	75.15	**1.31**	6	4.6
A. praecox-A × *A.* 'Finn'	17	51.01	65.19	**1.28**	3.3	3.11
A. praecox-C × *A.* 'Finn'	16	51.42	66.18	**1.29**	4.5	4
A. 'Streamline' × *A.* 'Finn'	30	56.1	72.94	**1.30**	5.2	4.56
A. 'Streamline' × *A.* 'Finn'	32	57.26	75.5	**1.32**	6.7	4.27
A. 'Streamline' × *A. praecox*-C	4	51.56	69.24	1.34	5.5	4.3
A. 'Streamline' × *A. praecox*-C	5	49.82	65.99	1.32	6.5	4.8
A. praecox-C × *A.* 'Streamline'	1	50.84	67.52	1.33	6	5
A. praecox-G × *A.* 'Streamline'	2	48.78	67.1	1.38	8	5
A. 'Streamline' (selfed)	37	60.28	80.76	1.34	4	3
A. 'Streamline' (selfed)	38	48.45	64.51	1.33	5.8	4.8
A. 'Streamline' (selfed)	39	54.68	72.58	1.33	6	5

6 Discussion

This study aimed to determine if certain cultivars of *Agapanthus* are safe for cultivation due to lower naturalisation and environmental risks associated with any reduced fecundity. Our findings show that dwarf cultivars should *not* be considered sterile or of low fertility per se and their fecundity needs to be critically evaluated following methods such as those presented here. Of the techniques we used, the minimum and most effective fecundity assessments are pollen fertility, self fertility, and cross fertility of cultivars with the typical tall-growing and naturalised *A. praecox* subsp. *orientalis*.

Our observations on accessions of the tall-growing *A. praecox* subsp. *orientalis* indicate that they have high fecundity in both female and male function. High cross (sib-) fertility and low self-fertility indicates that naturalised *A. praecox* subsp. *orientalis* is allogamous (out-crossing) and mostly self-incompatible (self-infertile). The low self-fertility of typical tall-growing *A. praecox* subsp. *orientalis* puts claims of low self-fertility and self-sterility of the cultivars into context; it is not an unusual condition.

There is evidence from herbarium collections (Appendix 4.2) that some dwarf cultivars have the ability to naturalise. In Matapouri, Northland, a single small-leaved plant with mauve flowers was collected growing in roadside gravel (AK 289229). This plant was most likely a cultivar (or seedling thereof) and most unlikely to have been planted (Figure 11). Another example is in Wellington City, where herbarium specimens (AK 301534, AK 301535, duplicate CHR 592780) were collected from numerous seedlings establishing in cracks in pavement. Nearby, a mature dwarf *Agapanthus* cultivar was growing en masse as council plantings and producing the seedlings.

All three dwarf cultivars that we tested under controlled conditions have the capacity to hybridise (in either direction) with the typical tall-growing *A. praecox* subsp. *orientalis* and produce germinable seed and healthy progeny. In domestic and public gardens, dwarf cultivars may be cultivated alongside tall-growing *A. praecox* subsp. *orientalis*. In the wild (fully naturalised environments), it is unlikely that they currently co-occur (i.e. they are not sympatric). Nevertheless, as documented above, some dwarf cultivars apparently have the capacity to establish in the wild, and if they do, our results suggest that they will be able to hybridise with naturalised tall-growing *A. praecox* subsp. *orientalis*. The dual abilities of cultivars to outcross and perhaps become naturalised support the desirability of growing *Agapanthus* cultivars that are of genuine low-fertility.

Of the two *Agapanthus* cultivars claimed to be of low fertility that we assessed, only *A.* 'Finn' is likely to have a low environmental impact. It is self-incompatible, has less than 10% cross fertility, and has reduced pollen viability. This establishes what we consider to be reasonable standards of infertility against which to test other cultivars.

Although *A.* 'Sarah' appears to be self-incompatible, its pollen viability and cross fertility as a male parent are too high to fully justify the 'eco-friendly' and 'low-fertility' marketing terms used for it. Striking differences between female and male performance of *A.* 'Sarah' are most likely attributable to its high inferred pollen viability compared with its aberrant female reproductive morphology (i.e. split styles and ovaries, deformed stigma, and lack of a pollination droplet).

Agapanthus 'Streamline' is demonstrated here to have high fertility, and an unusually high degree of self-fertility, suggesting a breakdown in any self-incompatibility system. Self fertility provides greater opportunities to naturalise from a single plant in the absence of other pollen parents. However, the weak growth of its seedlings arising through self-pollinations may suggest inbreeding depression, or, if the cultivar is of hybrid origin, genetic abnormalities of the F_2 progeny. To determine if there is a real loss of vigour the growth of these plants should be monitored for a longer time period. When outcrossed, *A.* 'Streamline' only exhibited minor differences in female versus male performance and the resultant seedlings were vigorous.

Although untested in this study, it is highly likely that other dwarf cultivars will show a wide range of fecundity. From our literature survey of cultivars of *Agapanthus* (Appendix 2 and 3), other purportedly sterile or claimed low-fertility cultivars include *A.* 'Baby Pete', *A.* 'Double Diamond', *A.* 'Goldstrike', *A.* 'Pavlova', *A.* 'Peter Pan' and *A.* 'Tinkerbell'. In particular, we consider that *A.* 'Double Diamond' should be re-located or re-imported into New Zealand for evaluation. It is a very good candidate to test for infertility because double flowers are a well-known cause of sterility[1]. *A.* 'Goldstrike', *A.* 'Peter Pan' and *A.* 'Tinkerbell' are readily available in this country. *A.* 'Baby Pete' and *A.* 'Pavlova' are subject to PVR applications and not yet available to the public; their fecundity should ideally be tested before being released commercially.

Once a cultivar is verified as being of true low fertility, best practice and vegetative propagation (preferably through rhizome division as discussed in Appendix 2) should be followed by nurseries to ensure that this low fertility is maintained. Seed propagation of cultivars is poor practice and may overcome any reduced fertility of the original cultivar and/or result in divergent growing on lines; neither is desirable.

Note that the fecundity assessments made here do not constitute weed risk assessments (sensu Pheloung et al. 1999), but do contribute to the understanding of breeding systems and reproduction in *Agapanthus*. As well as providing useful information to the ARC for their Auckland Regional Pest Management Strategy, this report can contribute to National Pest Plant Accord (NPPA) Technical Advisory Group (TAG) assessments and to DOC management of *Agapanthus*.

Although beyond the scope of this report and not as relevant for the Auckland Region, environmental impacts and weed risk assessments of the frost-tolerant deciduous species, and cultivars derived from them, should be considered for the cooler regions of New Zealand (Appendix 1). The species most likely to be used in the development of cultivars, other than *A. praecox*, is *A. inapertus*, an attractive pendulous-flowered plant. This deciduous species is from the mountainous areas of South Africa and can withstand sub-zero temperatures.

[1] Double flowers are often the result of anthers and other floral parts being converted into additional petals, causing sterility. For example, in heather (*Calluna vulgaris*) the fertile single-flowered species is a banned National Pest Plant Accord plant but its sterile double-flowered cultivars are exempt and allowed to be cultivated and sold in New Zealand.

6.1 Flow cytometry and chromosome numbers

Knowing the parentage of cultivars can be useful in elucidating causes of infertility. This is problematic for the majority of *Agapanthus* cultivars as parentages are seldom recorded (Appendix 3). Flow cytometry can be an effective tool for rapid screening to detect interspecific hybrids or possible chromosome differences; both conditions can result in impaired fertility.

The detection of interspecific hybrids using flow cytometry is reliant on the parent species having different genome sizes, such as the differences in DNA content between *A. campanulatus* and *A. praecox* (Zonneveld and Duncan 2003; Zonneveld in Snoeijer 2004).

Many of the *Agapanthus* cultivars arising through interspecific hybridisations are from *A. inapertus* and *A. praecox* crosses. Unfortunately, flow cytometric values of these two species are relatively similar (average DNA content 25.2 and 25.5 pg respectively; Zonneveld and Duncan 2003; Zonneveld in Snoeijer 2004) so it is unlikely that this technique will differentiate cultivars derived from this particular cross.

The cultivars tested here (*A.* 'Finn', *A.* 'Sarah' and *A.* 'Streamline') are not known to be interspecific hybrids (Appendix 2) and only *A.* 'Finn' had low DNA content values.

If the low-fertility of *A.* 'Finn', as determined by all of our assessments, is due to a hybrid origin (between *A. praecox* and a species with a lower average DNA content), then the low fertility may be due to hybrid sterility. However, a more likely explanation is that the low flow-cytometric values are attributable to the loss of one or two chromosomes (aneuploidy). In either case, the chromosome number of *A.* 'Finn' should ideally be determined by mitotic (diploid) counts to establish any aneuploidy and meiotic (haploid) observations to uncover any mispairing due to non-homologous chromosomes.

The poorer male performance of *A.* 'Finn' in outcrosses is probably due to its relatively low pollen viability (40%). Reduction in pollen viability is unusual and indicative of underlying abnormalities. Zonneveld and Duncan (2003) studied pollen viabilities in an extensive range of *Agapanthus* species, subspecies, cultivars and hybrids. They found that most taxa had very high pollen viabilities (>90%), that even confirmed hybrids had high pollen viabilities (c. 60–85%), and that only triploids had very low pollen fertility (1%, 4%, 74%).

Zonneveld and Duncan (2003) and Zonneveld in Snoeijer (2004) demonstrate that there is a range of genome sizes in their wide sampling of species and cultivars. Remarkably, none of the 130 cultivars they surveyed by flow cytometry were polyploid (triploid, tetraploid, or higher ploidy levels), but four (non-cultivar) plants (*A. africanus* and *A. inapertus* subspecies) were inferred to be triploid.

Other workers have found that tetraploids can arise spontaneously from the usual diploid material within tissue culture. Mori et al. (2007) encountered tetraploids in one line of *A. praecox* subsp. *orientalis*; the other lines were diploid, and all transgenic lines exhibited other somaclonal variation (in marker gene expression and morphological variation of vegetative and floral characteristics). Nakano et al. (2003) used both flow cytometry and chromosome counts to determine ploidy levels of explants of *A. praecox* subsp. *orientalis* 'Royal Purple Select' regenerated from tissue culture; they obtained diploid ($2n = 30$) and a high frequency of tetraploid ($2n = 60$) plants.

Other chromosome counts have previously been reported for *Agapanthus*. Most are diploid with chromosome counts of $n = x = 15$ and $2n = 2x = 30$ (e.g. Suge 1952; Lima de Faria 1953, 1954; Riley & Mukerjee 1962; Leighton 1965; Vijayavalli & Mathew 1990; Muzila & Spies 2005). Although Stenar (1933) reported $2n = 32$ for *A. africanus*, the majority of other counts for this species are the usual $2n = 30$. Suge (1952) examined mitotic chromosomes and meiotic pairing behaviour in an attempt to uncover the cause of low fertility in a plant of *A. africanus* (under its earlier name *A. umbellatus*) but encountered the usual chromosome number ($2n = 30$) and normal meiosis (bivalent formation). Leighton (1965) recorded B-chromosomes in *A. praecox*. Although not all taxa are currently recognised, Muzila and Spies (2005) counted five species, nine subspecies and 11 cultivars of *Agapanthus*, and in addition to the usual $2n = 30$, reported B-chromosomes for taxa including some *A. praecox* ($2n = 30+0–2B$) and a single taxon, *A. inapertus* subsp. *intermedius* with $2n = 28$ (+0–2B). As well as presenting their own chromosome counts, Muzila and Spies (2005) provide a useful table of previous counts in *Agapanthus*.

Our review of flow cytometry and chromosome numbers in *Agapanthus* reveals that, as far as we can determine, there are no currently available triploid cultivars of *Agapanthus*. Triploid plants are generally highly sterile (both in male and female function) providing great potential to deliberately produce a range of triploid *Agapanthus* selections. This should be achievable by first producing tetraploids (e.g. through tissue culture media incorporating mutagens such as colchicine), then crossing with outstanding but fertile diploid cultivars (such as *A.* 'Streamline') to produce sterile triploids from which to select cultivars. These selections would be unique and present new commercial opportunities both for the New Zealand domestic and international markets. Scientific breeding programmes of ornamentals are often lacking in New Zealand (as opposed to breeding of food crops), which is unfortunate considering that *Agapanthus* cultivars are significant export earners.

Figure 11 Small-leaved cultivar or seedling of *Agapanthus*, apparently naturalised: **A.** plant growing by roadside (arrowed), **B.** close-up showing mauve flowers and fine-leaved dwarf habit. Photos: Ewen Cameron

7 Conclusions

- The variety of techniques employed to objectively determine the levels of both male and female fertility of several cultivars and accessions of *Agapanthus* has been successful. We clearly uncovered a range of fecundity in the material examined, with the dwarf cultivar *A.* 'Finn' having the lowest fertility and the typical tall-growing *A. praecox* subsp. *orientalis* having the highest fertility across the various assessments.
- Because all material produced germinable seed none of the study group could be described as sterile. Of the various marketing terms used for *A.* 'Finn' and *A.* 'Sarah' ('Auckland safe', 'eco-friendly', 'sterile' and 'low-fertility'), none are appropriate for *A.* 'Sarah' and 'low-fertility' is the most accurate term for *A.* 'Finn'.
- *Agapanthus* 'Finn' is the only cultivar we tested likely to have a low environmental impact.
- There are opportunities to breed unique triploid cultivars that may be fully sterile.

8 Recommendations

- Using the benchmark results established by *A.* 'Finn', cultivars considered to be truly 'environmentally safe' should be self-sterile, have less than 10% cross fertility, and substantially reduced pollen viability.
- The methods employed here should be applied to objectively assess the fertility of other purportedly sterile or claimed low-fertility cultivars (e.g. *A.* 'Baby Pete', *A.* 'Double Diamond', *A.* 'Goldstrike', *A.* 'Pavlova', *A.* 'Peter Pan' and *A.* 'Tinkerbell'). These fertility assessments would create a list of genuine low-fertility *Agapanthus* cultivars that can be grown with the least chance of invasiveness.

9 Acknowledgements

Auckland Regional Council Biosecurity provided the *Agapanthus* research contract (0809/93/014) to Landcare Research for this project (2008–2010). Gary Houliston provided expertise in flow cytometry, and he, Peter Heenan and Lynley Hayes (Landcare Research) provided comments on a draft of this report. David Purcell (Landcare Research) maintained our study plants at the Landcare Research experimental gardens.

We thank the following for providing information on cultivars or supplying some of the plant material used in this study: Barrie McKenzie (Plant and Floral Intertrade), Bryan King (Kings Plant Barn), Ewen Cameron (Auckland War Memorial Museum), Ian Duncalf (Plant Struck, Tauranga), Ian Gear (In Gear Global), Jack Hobbs (Auckland Regional Botanic Gardens), Malcolm Woolmore (Lyndale Nurseries, Auckland), Richard Ware (Plant Production, Napier), Robert Bett (formerly of Lyndale Nurseries), Serra Kilduff (Plant Variety Rights Office, Christchurch) and Terry Hatch (Joy Plants).

Trevor James (AgResearch) kindly provided the cover image and Figure 2 and Ewen Cameron provided Figure 11.

10 References

Alexander MP 1980. A versatile stain for pollen, fungi, yeast and bacteria. Stain Technology 55: 13–18.

APG III 2009. An update of the Angiosperm Phylogeny Group classification for the orders and families of flowering plants: APG III. Botanical Journal of the Linnean Society 161: 105–121.

Auckland Regional Council (ARC) 2005. New plants suggested for pest control. Media release, 8 December 2005. (Available at www.arc.govt.nz/index.cfm?58A620FD-14C2-3D2D-B9CA-EA5858882785&objUUID=06EB20CE-BCD4-1A24-9CE4-4D129FCD2409).

Auckland Regional Council (ARC) 2007–2012. Regional Pest Management Strategy (RPMS). (Available at www.arc.govt.nz/index.cfm?02950186-145E-173C-9882-B5BEA1C13F5C).

Brickell CD, et al. (eds) 2009. International Code of Nomenclature for Cultivated Plants (ICNCP or Cultivated Plant Code) incorporating the Rules and Recommendations for naming plants in cultivation. 8th edn, adopted by the International Union of Biological Sciences International Commission for the Nomenclature of Cultivated Plants. Scripta Horticulturae (International Society of Horticultural Science) 10: 1–184.

Doležel J, Bartoš J 2005. Plant DNA flow cytometry and estimation of nuclear genome size. Annals of Botany 95(1): 99–110.

Gaddum M 1997. New Zealand Plant Finder. Auckland, David Bateman.

Gaddum M 1999a. The trade Plant Finder 1999–2000. Gisborne, New Zealand Plant Finder.

Gaddum M 1999b. Gaddum's Plant Finder 2000. Gisborne, New Zealand Plant Finder.

Gaddum M 2001. The trade Plant Finder 2001. Gisborne, New Zealand Plant Finder.

Healy AJ 1958. Contributions to a knowledge of the adventive flora of New Zealand, No. 6. Transactions of the Royal Society of New Zealand 85: 531–549.

Healy AJ, Edgar E 1980. Flora of New Zealand Volume III. Wellington, Government Printer. Pp. 47–48.

Howell C 2008. Consolidated list of environmental weeds in New Zealand. DOC Research & Development Series 292. Wellington, Department of Conservation.

Johnston JS, Bennett MD, Rayburn AL, Galbraith DW, Price HJ 1999. Reference standards for determination of DNA content of plant nuclei. American Journal of Botany 86: 609–613.

Kearns CA, Inouye DW 1993. Techniques for pollination biologists, University of Colorado Press.

Leighton FM 1965. The genus *Agapanthus* L'Héritier. Journal of South African Botany, supplementary volume IV.

Lima de Faria A 1953. The regions of special cycle of division of *Agapanthus* chromosomes. Chromosoma 6: 33–44.

Lima de Faria A 1954. Chromosome gradient and chromosome field in *Agapanthus*. Chromosoma 6: 330–370.

Mason T 1896 [1897]. An account of the plants growing at 'The Gums,' Taita. Transactions and Proceedings of the New Zealand Institute III – Botany 29: 393–412.

Mori S, Oka E, Umehara H, Suzuki S, Kobayashi H, Hoshi Y, Kondo M, Koike Y, Nakano M 2007. Somaclonal variation and stability of GUS gene expression in transgenic agapanthus (*Agapanthus praecox* ssp. *orientalis*) plants at the flowering stage. In Vitro Cellular and Developmental Biology – Plant 43: 79–87.

Muzila M, Spies JJ 2005. Chromosome counts in the genus *Agapanthus*. Bothalia 35: 109–110.

Nakano M, Tanaka S, Oota M, Ookawa E, Suzuki S, Saito H 2003. Regeneration of diploid and tetraploid plants from callus-derived protoplasts of *Agapanthus praecox* ssp. *orientalis* (Leighton) Leighton. Plant Cell, Tissue and Organ Culture 72: 63–69.

Neumann M 1952. New Zealand's sub-tropical area. The New Zealand Gardener 8: 691–695.

Pheloung PC, Williams PA, Halloy SR 1999. A weed risk assessment model for use as a biosecurity tool evaluating plant introductions. Journal of Environmental Management 57: 239–251.

Popay I, Champion P, James T 2010. An illustrated guide to common weeds of New Zealand. 3rd edn. Christchurch, New Zealand Plant Protection Society. 448 p.

Redgrove H 1991. A New Zealand handbook of bulbs and perennials. Auckland, Godwit Press. 299 p.

Riley HP, Mukerjee D 1962. Chromosomes of some species of *Agapanthus*. Cytologia 27: 325–332.

Snoeijer W 2004. *Agapanthus*: a revision of the genus. Portland, OR, USA, Timber Press. 320 p. (Available from Google books).

Stenar H 1933. Zur embryologie der *Agapanthus*-gruppe. Botaniska Notiser 2: 520–530.

Suge H 1952. Cytological studies on *Agapanthus umbellatus* L'Her, with special regard to the cause of sterility. Japanese Journal of Genetics 28: 43–46.

Thompson W 2006. Gardeners seek agapanthus reprieve. *New Zealand Herald*, Feb 17, 2006. (Available at www.nzherald.co.nz/gardening/news/article.cfm?c_id=218&objectid=10368803).

van Dijk H 2004. *Agapanthus* for gardeners. Portland, OR, USA, Timber Press. (Available from Google books.)

Vijayavalli B, Mathew PM 1990. Cytotaxonomy of the Liliaceae and allied families. Tirvandrum, Continental. 242 p.

Williams P, Thompson W 2006. *Agapanthus* joins planned hit-list for national ban. *New Zealand Herald*, 30 January 2006. (Available at www.nzherald.co.nz/nz/news/article.cfm?c_id=1&objectid=10366111).

Zimer E 2008. *Agapanthus praecox* ssp. *orientalis* (F. M. Leighton) F. M. Leighton 1965. (Available at http://eduart.007sites.com/ONP/Agapanthus%20praecox%20ssp%20orientalis.pdf and www.fileden.com/files/2008/5/20/1920751/O%20N%20P/Agapanthus%20praecox%20ssp%20orientalis.pdf).

Zonneveld BJM, Duncan GD 2003. Taxonomic implications of genome size and pollen colour and vitality for species of *Agapanthus* L'Héritier (Agapanthaceae). Plant Systematics & Evolution 241: 115–123.

Websites (all accessed October 2010)

Agapanthus Direct: www.agapanthusdirect.com

Agapanthus praecox: www.plantzafrica.com/plantab/agapanpraecox.htm

Alluring Agapanthus: http://gardeningisezee.com/?p=390

Anthony Tesselaar Plants: www.tesselaar.com/plants/stormagapanthus

Bloomz New Zealand: http://bloomz.co.nz

Diacks Nursery Catalogue, June 2010: www.diacks.co.nz/PAGES/Tree%20and%20Shrub%202010.pdf

IPONZ – Plant Variety Rights Register: http://202.174.112.149 and www.iponz.govt.nz/cms/pvr

KiwiGold®: www.kiwigoldnz.com

Landcare Research Poisonous Plants in New Zealand – external poisons (skin irritants): www.landcareresearch.co.nz/publications/infosheets/poisonplants/poisplants_external.asp

Lyndale Nurseries: www.lyndale.co.nz

Mary Robertson website: www.maryrobertson.co.nz/agapanthus.html

New Zealand Plant Finder online: www.plantfinder.co.nz

NPPA TAG Assessment: www.biosecurity.govt.nz/files/pests/plants/nppa/nppa-tag-assessments.pdf

Papers Past (digitised historic New Zealand newspapers): http://paperspast.natlib.govt.nz

Plantlife Propagators: www.plantlife.co.nz

Plantman: www.plantman.co.nz

Plant Production: www.plantproduction.co.nz

US Plant Patent Applications: http://patft.uspto.gov

Vanplant: www.vanplant.co.nz/agapanthus.htm

Weedbusters: www.weedbusters.co.nz/weed_info/detail.asp?WeedID=34

Weeds of Blue Mountains Bushland: *Agapanthus praecox* ssp. *orientalis*: www.weedsbluemountains.org.au/agapanthus.asp

Appendix 1 – Taxonomy and species of *Agapanthus*

Agapanthus is a genus of herbaceous perennial monocots that are endemic to South Africa (Leighton 1965). They have been placed in several different families including the Liliaceae, Alliaceae, and in their own family the Agapanthaceae. The latest classification is based on DNA sequencing studies and places *Agapanthus* in the Amaryllidaceae family (APG III 2009).

The most recent revision of *Agapanthus* is by Snoeijer (2004) who accepted Zonneveld and Duncan's (2003) proposal to recognise six (instead of 10) species equally divided into two sections:

1. Section Lilacinipollini (deciduous, frost-tolerant, leaf usually with a purple base, pollen purple, nrDNA content 22.3–24.0 pg):

   A. campanulatus (subspp. *campanulatus* and *patens*)

   A. caulescens (subspp. *angustifolius*, *caulescens* and *gracilis*)

   A. coddii.

2. Section Ochraceipollini (deciduous or evergreen, frost-tender or tolerant, leaf usually with a green or purple base, pollen yellow, nrDNA content 25.2–31.6 pg):

   A. africanus (subspp. *africanus* and *walshii*)

   A. inapertus (subspp. *inapertus*, *hollandii*, *intermedius*, *parviflorus* and *pendulus*)

   A. praecox (subspp. *minimus*, *orientalis* and *praecox*).

Of these, the following species and subspecies are likely to be present in New Zealand:

A. campanulatus (and/or *A. campanulatus* subsp. *patens*; AK 228172)

A. coddii (AK 232421)

A. inapertus (AK 221730, AK 228161, AK 291579 and/or *A. inapertus* subsp. *pendulus*)

A. praecox subsp. *orientalis*, *A. praecox* subsp. *minimus* (AK 301534, AK 301535), and possibly *A. praecox* subsp. *praecox* (AK 218779, AK 291578)[2].

[2] Two subspecies of *Agapanthus praecox*, subspp. *orientalis* and *praecox*, are similar and difficult to distinguish. There are only two New Zealand herbarium specimens tentatively identified as *A. praecox* subsp. *praecox* (both at Auckland War Memorial Museum, AK 218779 and AK 291578). Although this material best fitted descriptions of *A. praecox* subsp. *praecox*, because of the taxonomic difficulties their identifications cannot be assured (Ewen Cameron, pers. comm.).

The remaining species of *Agapanthus*, *A. caulescens*, appears to be absent from New Zealand as we have found no records of it (Appendices 3 and 4.2).

Most validating herbarium specimens are of the widespread *A. praecox* subsp. *orientalis* (including the names *A. orientalis* and *A. praecox* – see Appendix 4.2). However, because it is such a well-known and familiar plant, it is often overlooked and consequently under-collected in herbaria. Hence, its distribution is more widespread than indicated in Figure 1 and Appendix 4.2. Note also that the data sourced via the New Zealand Virtual Herbarium (and Figure 1) do not distinguish between cultivated and naturalised herbarium specimens.

Although specimens under the name *A. africanus* are vouchered for New Zealand, we are not certain that the bona fide species is present in this country, as Snoeijer (2004) states that *A. africanus* is very difficult to grow and almost all selections associated with it are in fact cultivars or hybrids. On the other hand, Snoeijer (2004) may have written this from a European (UK and The Netherlands) cool-climate perspective whereas the two New Zealand specimens named as *A. africanus* are from warm-temperate regions (AK 149332, locally well-established at a site in Kawerua, near Waipoua State Forest; AK 228173, cultivated at Auckland Botanic Gardens; Appendix 4.2).

The relatively frost-tender and evergreen species can withstand an average minimum temperature of about −1°C (= Climate Zone 10 in Snoeijer 2004). These species (e.g. *A. africanus*, if present; *A. praecox*) are more likely to become naturalised in the milder, areas of New Zealand, as indeed *A. praecox* subsp. *orientalis* is vigorously naturalising in the wider Auckland region. Conversely, the cold-tolerant and deciduous species (e.g. *A. campanulatus*, *A. caulescens*, *A. coddii* and *A. inapertus*), and some cultivars derived from them, may survive much colder temperatures (perhaps as cold as −12 to −17°C; = Zone 7 in Snoeijer 2004). These are likely to grow in inland, southern, mountainous and cooler regions of New Zealand and potentially pose a previously unrecognised environmental risk.

Appendix 2 – Cultivars of *Agapanthus*

Cultivars are evergreen or deciduous. They range in stature from about 200 to 500 mm for the low-growing (so-called 'dwarf') selections; from 600 mm to 1.2 m for medium-sized selections; and up to 1.8(–2) m, including flower stems, for the tallest cultivars. Leaves are usually green or with a blue-green waxy (glaucous) surface, and sometimes with a purple base; other cultivars have green leaves with white or yellow variegation. Flower colours of the cultivars are in numerous shades of violet, blue, lavender and purple, with several white-flowered selections. Most have flowers with six tepals, although there are a few semi-double selections with a greater number of tepals. Snoeijer (2004) arranged cultivars in several groups including those with funnel-, trumpet-, salver-, and tubular-shaped flowers. Despite this range of variation, many of the medium-sized, non-variegated, blue-flowered selections are very similar to one another.

Vegetative propagation, usually through division of their rhizomes, is the best method to maintain the uniformity of the numerous *Agapanthus* cultivars (van Dijk 2004). Tissue culture of *Agapanthus* may produce some variation and Snoeijer (2004) cites a figure of 3–5% instability through micropropagation. Offering named cultivars as seed is poor practice and can create variation that undermines the integrity of the cultivars, resulting in several different plant lines under the same cultivar name. As Snoeijer (2004) and van Dijk (2004) note, *Agapanthus* is easy to grow from seed which is why nurseries extensively offer seed-propagated material as cultivars, and this is also true in New Zealand.

Snoeijer (2004) lists 625 cultivars of *Agapanthus* worldwide. These are derived mainly from evergreen species and subspecies, and particularly from *A. praecox* subsp. *orientalis*. However, cultivars are derived from other taxa, and through hybridisation between them. For example, *A. praecox* subsp. *minimus* and the deciduous species *A. inapertus* have been important parents. Note that the exact details of the parentages of many cultivars are unknown, complex or only partially recorded.

About 60–80 cultivars of *Agapanthus* have been available from the New Zealand nursery trade and many have originated in this country (Appendix 3). Like the majority of cultivars in *Agapanthus*, most have originated from *A. praecox* subsp. *orientalis* and hybridisation, and details of their parentages may be poorly recorded. *Agapanthus* 'Purple Cloud' and *A.* 'Small Dark' are examples of putative interspecific hybrids bred in New Zealand.

Dwarf cultivars

Many dwarf cultivars are likely to be selections made from *A. praecox* subsp. *minimus* or of hybrids with that subspecies. These low-growing cultivars are popular for their tidy and compact growth habit and are well suited to smaller gardens.

One of the most popular low-growing cultivars in New Zealand is *A.* 'Streamline' (Figure 5). It has a long flowering season and sky-blue flowers and was propagated from a previously unnamed plant growing at the Auckland Botanic Gardens. This plant impressed an evaluation panel led by the late George Rainey who gave it its name (Jack Hobbs, pers. comm.). *A.* 'Streamline' has been available since about 1991.

Several dwarf cultivars said to be of low fertility have become available on the New Zealand market over the last decade.

Agapanthus 'Finnline' and *A.* 'Finn' were both raised by Ian Duncalf and named after his youngest son. *A.* 'Finnline' is a variegated white-flowered cultivar selected from amongst a batch of an *A. praecox* (non-variegated) tissue-cultured line. The fact that it arose within the micropropagation environment supports the comment made earlier that there is indeed a percentage of instability when propagating *Agapanthus* through tissue culture. *A.* 'Finnline' was first offered for sale on 15 April 2002. It has a distinctly compact and dwarf growth form and silvery-grey variegation. It is essentially a foliage plant as *A.* 'Finnline' does not flower freely and the flowers are a little distorted. It is considered sterile by Ian Duncalf (pers. comm.) as he has not observed any seed production. A few nurseries still grow *A.* 'Finnline' but it is slow to propagate in commercial quantities. *A.* 'Finn' (Figure 3) originated as a 'sport' (a visible asexual mutation) from *A.* 'Finnline'. *A.* 'Finn' arose outside of tissue culture and is a reversion to non-variegation.

Agapanthus 'Sarah' (Figure 4) has distinctly arranged upward-pointing florets producing a candelabra-shaped umbel, bicoloured florets and soft blue flowers and dark green foliage. It was raised in 1993 by the late Mike Geenty in Hamilton, New Zealand, through a controlled breeding programme. The female parent was an unnamed *A. praecox* seedling, 'characterised by its strong stem, blue to lilac flower colour and leaf colour atypical for *A. praecox*'. The male parent was a proprietary *A. praecox* seedling, 'characterised by its profuse florets and leaf colour atypical for *A. praecox*'. The flowering progeny was selected in 1996 (United States patent application PP13236).

Agapanthus 'Finn' first came on the market 20 September 2005 (Serra Kilduff, pers. comm.) and *A.* 'Sarah' was listed by Gaddum (2001); both received New Zealand Plant Variety Rights in 2009 (*NZPVR Journal*, No. 117, 14 April 2009). They have been described variously in nursery catalogues as sterile, low-fertility, 'eco-friendly', or 'Auckland safe' (Appendix 3).

Agapanthus 'Goldstrike' was raised by Ian Gear in 1990 when he owned Heritage Horticulture nursery in Hamilton (Ian Gear, pers. comm.). It arose as a chance variegated seedling from a batch of seed of a non-variegated plant. *Agapanthus* 'Goldstrike' is named after its striking golden-yellow margin on the outside edges of the leaves, contrasting with grey and bluish toned longitudinal stripes. It has a compact growth habit and dark blue flowers on black stems. Like many cultivars its exact parentage is unknown, but (although evergreen) *A.* 'Goldstrike' does have *A. inapertus* in its parentage. It must be propagated by rhizome division as tissue culture is not successful. Ian Gear and Malcolm Woolmore (pers. comm.) consider *A.* 'Goldstrike' to be sterile or of very low fertility as under the conditions where they have grown the selection it sets almost no seed and the seed that is produced has not germinated for them. *A.* 'Goldstrike' was provisionally called *A.* 'Geagold' (Snoeijer 2004) but it was never sold under this name. *A.* 'Goldstrike' is one of the best variegated *Agapanthus* and is marketed by Lyndale Nurseries under the KiwiGold® label (www.kiwigoldnz.com).

Earlier purported sterile or low-fertility dwarf *Agapanthus* sold in New Zealand are *A.* 'Peter Pan' and its variegated sport *A.* 'Tinkerbell' (both listed by Gaddum 1997).

Agapanthus 'Peter Pan' is a selection of *A. praecox* subsp. *minimus* raised by J.N. Giridlian's Oakhurst Gardens, California, USA, in 1949. Snoeijer (2004) comments that it is still widely cultivated but mainly propagated by seed. This comment appears to contradict some New Zealand nurseries who claim that it is sterile or self-sterile. Because of its long history of cultivation, and the variation induced through seed propagation, it is possible that selected strains have been developed with lower fertility. According to Malcolm Woolmore (pers. comm.), the late Mike Geenty was said to have developed a supposedly 'sterile' strain and it is this that Lyndale Nurseries vegetatively propagate via division of rhizomes. Lyndale Nurseries note that it produces seed when grown in the vicinity of other *Agapanthus* but consider that it is self-sterile (Malcolm Woolmore, pers. comm.).

The variegated cultivar *A.* 'Tinkerbell' has also been claimed to be sterile or semi-sterile. It was raised in New Zealand by Barrie McKenzie (of the now defunct Topline Nurseries in Oratia) in the late-1970s. It arose as a single variegated seedling from a seed lot imported from California of *A.* 'Peter Pan'. Bryan King of North Shore Nurseries (the wholesale part of Kings Garden Centre, which later became King's Plant Barn) obtained propagation material from Barrie McKenzie and bulked-up and marketed it in the late 1970s or early 1980s (much earlier than 1991 stated by Snoeijer (2004)). Although it has a reputation as a shy flowerer, there are apparently also plants under that name that are free-flowering. It was named *A.* 'Tinkerbell' alluding to its parent *A.* 'Peter Pan' (Barrie McKenzie and Bryan King, pers. comm.).

Agapanthus 'Baby Pete' and *A.* 'Pavlova' are new dwarf cultivars that are also claimed to be sterile or of very low fertility. They are subject to PVR applications and both selections are intended to be available to the public in New Zealand from spring 2011 (Malcolm Woolmore, pers. comm.).

Agapanthus 'Baby Pete' is a dwarf cultivar with pale blue flowers. It was imported from Australia and Lyndale Nurseries are licensed to grow it in New Zealand (Malcolm Woolmore, pers. comm.).

Agapanthus 'Pavlova' is a dwarf cultivar with creamy-white flowers and a blue-grey leaf that will also become available from Lyndale Nurseries. It was raised sometime prior to 2000 by Terry Hatch (Joy Plants, Pukekohe). It arose as a single hybrid plant among a batch of *A. inapertus* seedlings and the pollen parent is probably *A. praecox*. None of the plants propagated and named *A.* 'Pavlova' have appeared to set seed (Terry Hatch and Malcolm Woolmore, pers. comm.).

Agapanthus 'Double Diamond' is a dwarf selection with white double flowers. These double flowers, usually composed of 8–10 tepals, may be responsible for the stated sterility of this cultivar (see Discussion). It was raised by Jim Holmes of Cape Seed & Bulb, South Africa, and known since 2000 when Plant Variety Rights was applied for (Snoeijer 2004). *A.* 'Double Diamond' has been commercially available since 2003 and is currently sold in South Africa, the UK, France, Ireland, Israel, and Spain. It was imported into New Zealand for a time but not commercially released (Barrie McKenzie, pers. comm.).

Appendix 3 – *Agapanthus* species and cultivars recorded from New Zealand

This appendix lists species and cultivars thought to be present in New Zealand[3] from horticultural resources. The most comprehensive listing for New Zealand is Gaddum (1997, 1999a, 1999b, 2001); the most authoritative sources are the New Zealand Plant Variety Rights Register and Snoeijer (2004). Snoeijer's (2004) revision includes details of origin, leaf, flower colour, and notes and should be consulted for detailed information on each cultivar.

Key to abbreviations for the source of records (websites accessed October 2010):

AD = Agapanthus Direct: www.agapanthusdirect.com

BL = Bloomz New Zealand: http://bloomz.co.nz

DI = Diacks Nursery Catalogue, June 2010: www.diacks.co.nz/PAGES/Tree%20and%20Shrub%202010.pdf

LYN = Lyndale Nurseries: www.lyndale.co.nz

MR = Mary Robertson website: www.maryrobertson.co.nz/agapanthus.html

PF = New Zealand Plant Finder online (www.plantfinder.co.nz) and print (Gaddum 1997, 1999a, 1999b, 2001).

PL = Plantlife Propagators: www.plantlife.co.nz

PM = Plantman: www.plantman.co.nz

PP = Plant Production: www.plantproduction.co.nz

PVR = IPONZ - Plant Variety Rights Register: www.iponz.govt.nz/cms/pvr

RED = Redgrove H 1991. A New Zealand handbook of bulbs and perennials.

VP = Vanplant: www.vanplant.co.nz/agapanthus.htm

WS = Snoeijer W 2004. *Agapanthus*: a revision of the genus.

Names in bold are the accepted plant names that are well referenced and comply with the International Code of Nomenclature for Cultivated Plants (Brickell et al. 2009).

[3] Excluded from this list are two cultivars (*A.* 'Ice Maiden' and *A.* 'Neuseeland') that originated in New Zealand but are not available under those names here. According to Snoeijer (2004) both cultivars were collected as unnamed plants from New Zealand and introduced (and presumably named) in Germany. Also excluded is *A.* 'Double Diamond', a cultivar imported into New Zealand but never sold (Barrie McKenzie, pers. comm.).

***Agapanthus* species/cultivar**	**Source of record and notes**	**Comments**
A. 'Africans Blue'	PF	
A. 'Albus Roseus' (Funnel Group)	PF [as *A.* alboroseus and *A.* 'Albus Roseus'] PM [as *A.* 'Alba Rosea'] RED: As 'Albus' but flowers show a tinge of pink with age. WS: Introduced in New Zealand, known since 1991, and still in cultivation…invalid name.	
***A.* 'Baby Pete'**		A new dwarf cultivar with pale blue flowers, claimed to be sterile or of very low fertility, not yet available to the public and subject to a PVR application (Malcolm Woolmore, pers. comm.).
***A.* 'Black Pantha'** (Funnel Group)	PVR HOM092: Breeder: G. Morrison, 162 Williamson Road, Doncaster, Victoria, Australia. Expiry Date: 28/2/2025. WS: (chance seedling of ***A. praecox* subsp. *orientalis***), raised by G. Morrison, Doncaster, Victoria, Australia, known since 1999.	
***A.* 'Blue Baby'** (Funnel Group)	BL: Soft blue (dwarf) [flowers]. 0.35–0.5 m. MR [as *A.* 'Baby Blue']: This is the smallest and most compact growing of the *Agapanthus*. A mass of 20 to 30 cm flower spikes carry small balls of true blue. PF [as *A.* 'Baby Blue' and ***A.* 'Blue Baby'**] PL: Dwarf, blue-flowered form. RED: Probably a cultivar of *A. africanus*, growing to 60 cm (24 in.), with light blue flowers on rather open heads in summer. WS: From New Zealand, known since 1987, and still in cultivation. Also offered as seed.	Seed propagation may undermine the uniformity of this cultivar. Probably not a cultivar of *A. africanus* as claimed by Redgrove (1991) as that species may be absent from New Zealand.
***A.* 'Blue Blazer'**	DI	
***A.* 'Blue Boy'**	BL: Mid blue [flowers]. Massive head. 0.8 m. PF PM: Compact broad foliage with deep blue flowers. WS: Offered by Diacks [Nurseries Ltd], New Zealand, known since 1998.	

***Agapanthus* species/cultivar**	**Source of record and notes**	**Comments**
***A.* 'Blue Brush'** (Funnel Group)	PF [as *A.* 'Fragrant Blue'] PVR HOM121: Breeder's Reference: Blue Brush. Breeder: V.J. Hooper, 45 The Drive, Tauranga, NZ. PVR terminated: 31/7/2007. WS: Raised by V.J. Hooper, Tauranga, New Zealand, in 2000; known in the UK since 2001 when offered by Fairhaven Nurseries.	Trade name: *A.* 'Fragrant Blue'.
***A.* 'Blue Dot'**	DI: Very hardy blue flowering variety. Ideal for driveways, rockeries. Suits most conditions. Will grow in full wind dry/wet…grows to 40 cm PF WS: Known since 1997, New Zealand, and still in cultivation.	
***A.* 'Blue Horizons'**	PVR HOM104: Breeder: Lyndale Nurseries Auckland Ltd, P.O. Box 81-022, Whenuapai, Auckland, NZ. Application withdrawn: 30/9/2002. WS: Raised by Lyndale Nurseries Auckland Ltd, New Zealand, known since 2000.	
***A.* 'Blue Ice'** (Funnel Group)	PF WS: Raised by Dick Fulcher, Pine Cottage Plants, UK, known since 2001.	
A. 'Blue Isle'	BL: Soft blue [flowers], purple rib. 0.8–1.0 m.	Possibly a name in error.
***A.* 'Blue Mountain'**	PF PVR HOM057: Breeder: D. Hughes, Blue Mountain Nurseries, 99 Bushy Hill Street, Tapanui, West Otago, NZ. Expiry date: 30/7/2017. WS: Raised by D. Hughes, Blue Mountain Nurseries, Tapanui, New Zealand, known since 1996.	
***A.* 'Blue Nile'** (Funnel Group)	PF RED: Massive heads of mauve flowers to 1.8 m (6 ft) and broad foliage typical of *A. orientalis*. WS: (selection of ***A. praecox* subsp. *orientalis***): Known since 1991, New Zealand, and still in cultivation.	
***A.* 'Blue Skies'**	PF RED: Good full heads of sky-blue flowers to 60 cm (24 in.) from midsummer onwards. WS: Probably from New Zealand. Known since 1991 and still in cultivation.	

***Agapanthus* species/cultivar**	**Source of record and notes**	**Comments**
***A.* 'Bluestorm'** (Funnel Group)	WS: New Zealand. Known since 2002 when introduced by Anthony Tesselaar, California, USA.	Low growing selection claimed to have originated in New Zealand by Snoeijer (2004), but stated as having been developed in Australia at www.tesselaar.com/plants/stormagapanthus/. If it is sold at all in New Zealand, it is not commonly available here.
A. campanulatus F.M.Leight.	BL [as *A. campanulata*]: Soft blue [flowers]. Slender stems. 1.0 m. PF [as *A. campanulatus*, *A. campanulatus* 'Deep Purple', *A. campanulatus* hybrids] WS	Often sold as seed in New Zealand so various names are included under the species.
A. coddii F.M.Leight.	PF [as *A. codii*] WS	
***A.* 'Crystal Drop'** (Tubular Group)	MR [as *A.* 'Crystal Drops']: A taller grower with 60 cm flower stems. The white flowers have a soft pink blush and are pendulous. PF WS: New Zealand, known since 1996, and still in cultivation.	Flowers are tinged pale blue (not soft pink as stated by MR). Introduced by the former Topline Nurseries in Oratia (Barrie McKenzie, pers. comm.).
A. 'Dwarf Blue' (Funnel Group)	AD PF WS	Because of seed propagation, the true plant is probably no longer in cultivation – see Snoeijer (2004).
A. 'Dwarf White'	AD BL: White [flowers]. 0.35–0.5 m. PF WS	Because of seed propagation, the true plant is probably no longer in cultivation – see Snoeijer (2004).
***A.* 'Finn'**	LYN: (Auckland Safe): A green-leaved sport of ***A.* 'Finnline'** (PVR). Neat green foliage topped with attractive pure white flower heads. Hardy. 0.5 x 0.5 m. PL: Sterile med. white, free flowering. PVR applied for. PM: Neat green foliage. Pure white blooms on green stems. Eco-friendly low fertility variety. PVR HOM231: Breeder: Ian Duncalf, 139 Te Puna Road, R.D.6, Tauranga, NZ. Expiry date: 30/3/2029.	Possibly as *A.* 'Fin' in Snoeijer (2004).

***Agapanthus* species/cultivar**	**Source of record and notes**	**Comments**
***A.* 'Finnline'** (Variegated Leaf Group)	PF PVR HOM161: Breeder: Plant Struck Ltd, 139 Te Puna Road, R.D.6, Tauranga, NZ. Application withdrawn: 8/7/2004. WS: Raised by Parva Plants, New Zealand, known since 2003.	A variegated cultivar raised by Ian Duncalf (pers. comm.) who considers it to be sterile.
***A.* 'Flore Pleno'**	PF [as *A.* 'Flore Plena' and ***A.* 'Flore Pleno'**]. RED: A rare and interesting, lower-growing, double-flowered variety of *A. orientalis*; methyl-violet. WS: Known since 1878 in France, 1885 in England, and 1888 in The Netherlands…	
A. 'Gael's Sapphire'	PF	Uncertain of the validity of this cultivar; listed in online version of the New Zealand Plant Finder only.
A. 'Gayle's Lilac' (Funnel Group)	DI [as *A.* 'Gayles Lilac']: A very hardy Agapanthus. Will grow in full shade or full sun. Lilac blue flowers in midsummer. Ideal for borders. Grows to 60 cm. PF [as *A.* 'Gayles Lilac'] WS: Introduced in New Zealand, known since 1997, and still in cultivation…invalid name.	
***A.* 'Getty White'** (Funnel Group)	PF WS: Introduced in the USA, known since 1990 in the UK when offered as seed. Still in cultivation.	
***A.* 'Glen Avon'** (Funnel Group)	PF [as *A.* 'Fragrant Glen' and ***A.* 'Glen Avon'**] PVR HOM066: Address for service: Lifetech Laboratories, 224 Albany Highway, Albany, Auckland, NZ. Breeder: A.D. Gray, 24B Alberta Road, Glen Avon, New Plymouth, NZ. PVR terminated: 8/3/2007. WS: Raised by A.D. Gray, Glen Avon, New Plymouth, New Zealand, known since 1997, and still in cultivation.	Trade name: *A.* 'Fragrant Glen'

***Agapanthus* species/cultivar**	**Source of record and notes**	**Comments**
***A.* 'Goldstrike'** (Variegated Leaf Group)	PF [as *A.* 'Gold Strike'] PVR HOM054 [as *A.* 'Geagold']: Breeder: I.R. Gear, 53a Coroglen Rise, Pukerua Bay 5026, NZ. Application lapsed: 13/1/1999. PVR HOM250: Address for service: Lyndale Nurseries, Whenuapai, Auckland, NZ. Breeder: I.R. & S.H. Gear Family Trust, 53a Coroglen Rise, Pukerua Bay 5026, NZ. Expiry date: 12/3/2030. WS [as *A.* 'Geagold']: Raised by I.R. Gear, Heritage Horticulture, New Zealand, known since 1995, and still in cultivation.	A dwarf cultivar with variegated leaves and navy blue flowers. Claimed to be sterile or of very low fertility (Ian Gear and Malcolm Woolmore, pers. comm.). Described (as *A.* 'Gold Strike') in its USPTO Patent Application (http://patft.uspto.gov/netacgi/nph-Parser?Sect1=PTO2&Sect2=HITOFF&u=%2Fnetahtml%2FPTO%2Fsearch-adv.htm&r=5&p=1&f=G&l=50&d=PTXT&S1=Agapanthus&OS=Agapanthus&RS=Agapanthus).
***A.* 'Hazy Days'**	BL: Lavender [flowers]. 1.5 m. PF WS: Known since 1997 when offered by Diacks [Nurseries Ltd], New Zealand, and still in cultivation.	
A. Headbourne Hybrids	PF WS: A group of plants raised by Lewis Palmer, Winchester, Hantshire, UK…	Many different selections and hybrids are offered under this name – see Snoeijer (2004).
***A.* 'Hinag'** (Variegated Leaf Group)	PVR HOM138: Breeder: R.A. Mendoza, Santa Ana, California, USA. Application withdrawn: 24/2/2003. WS: Trade name Summer Gold…(seedling of **'Peter Pan'** pollinated by unknown parent, probably a variegated plant) raised by Ramon Alaniz Mendoza, California, USA, in 1986. Introduced by Hines Horticulture, also of California, and still in cultivation.	
***A.* 'Ice Queen'** (Trumpet Group)	PF WS: Offered by Mill House Nursery, Akaroa, New Zealand, who obtained the plant from Bay Bloom Nurseries, Tauranga, New Zealand, in November 1994.	
A. inapertus Beauverd ex F.M.Leight.	PF WS	
A. inapertus* subsp. *pendulus (L.Bolus) F.M.Leight.	PF WS	

Agapanthus **species/cultivar**	**Source of record and notes**	**Comments**
A. **'Isis'** (Salver Group)	PF WS: (probably a selection of ***A. campanulatus***): Raised and introduced by Bloom, Bressingham Gardens, UK. Known since 1968 and still in cultivation. Also offered as seed.	
A. **'Jack's Blue'** (Funnel Group)	PF [as *A.* 'Jackis Blue' and ***A.*** **'Jack's Blue'**] WS: New Zealand, known since 2001 when offered widely in the UK…[named after] Jack Blyth, a New Zealand nurseryman.	
A. **'Kingston Blue'** (Salver Group)	PF WS: (selection of *A. campanulatus* subsp. *patens*): Introduced by Miss Raphael, Kingston Bagpuize, UK. Known since 1990 and still in cultivation. Also offered as seed.	
A. **'Lapis'**	PVR HOM162: Address for service: Balnahar Grove Nursery (M. & M. McBeath), 2160 Maungatautari Road, R.D.2, Cambridge, NZ. Breeder: V. Hooper, 24 Sole Avenue, New Plymouth, NZ. Expiry date: 16/6/2025.	
A. **'Lavender Haze'**	PF PVR HOM133: Address for service: Lifetech Laboratories, 224 Albany Highway, Albany, Auckland, New Zealand. Breeder: R.J. & D.M.L. Wood, 226 Corbett Road, R.D.3, New Plymouth, NZ. PVR terminated: 28/4/2007. WS: Raised by R.J. and D.M.L. Wood, New Plymouth, New Zealand, known since 2001.	
A. 'Mid Blue'	PF [sold as seed] WS: Known since 1997, New Zealand, and still in cultivation…invalid name.	Seed propagation may undermine the uniformity of this cultivar, if it is distinct at all.
A. **'Milky Blue'**	PF [sold as seed] WS: Known since 1997, New Zealand. Also offered as seed.	Seed propagation may undermine the uniformity of this cultivar.
A. 'Mini Blue'	PF WS: known since 1997, New Zealand. Invalid name…	Possibly = *A.* 'Blue Baby'?
A. 'Mini White'	PF	Invalid name. Possibly = *A.* 'Dwarf White' and/or *A.* 'White Baby'?

***Agapanthus* species/cultivar**	**Source of record and notes**	**Comments**
A. 'Moonshine'	PF	Listed in online version of the New Zealand Plant Finder only. Possibly the same cultivar as *A.* 'Moonbeam' which is not yet available pending a PVR application (Richard Ware, pers. comm.)
A. 'Natalensis'	BL: Rich purple [flowers]. Deciduous. 1.0 m. PF [as *A. natalensis*] WS: Known since 1997, New Zealand, and still in cultivation…probably a form of ***A. campanulatus***…invalid name…	
***A.* 'Newstead Blue'**	PF WS: Known since 1998 when offered by Diacks [Nurseries Ltd], New Zealand, and still in cultivation.	
A. 'Nimbus'	PF	The single record for that cultivar name is in Gaddum (2001), as available from Port Perennials, Dunedin, a nursery that no longer appears to be in business.
***A.* 'Pavlova'**		A new dwarf cultivar with creamy-white flowers, claimed to be sterile or of very low fertility, not yet available to the public and subject to a PVR application (Terry Hatch and Malcolm Woolmore, pers. comm.).

Agapanthus **species/cultivar**	**Source of record and notes**	**Comments**
A. **'Peter Pan'** (Funnel Group)	AD DI: Dwarf African lily with blue flowers. Ideal for tub and under tree plantings. Excellent contrast for landscaping...grows to 50 cm. LYN: The true sterile form. Tidy compact clumps topped with sky blue flowers highlighted with dark blue picotee. Excellent for mass planting. Hardy. 0.5 x 0.5 m. MR: A medium sized compact grower with shorter broad leaves. This variety always has a flower or two throughout the year with the main flowering in early summer. Balls are mid blue in colour. PF PL: Free-flowering dwarf blue. Self-sterile flower clusters. RED: Narrow leaves, heads of blue flowers to 50 cm (20 in.). WS: (selection of ***A. praecox*** **subsp. *minimus***): Raised by J.N. Giridlian's Oakhurst Gardens, California, USA, in 1949. Still widely cultivated but mainly propagated by seed, which is offered through the world…despite its being among the most widely grown seed-propagated plants, some nurseries state that the plant is sterile.	Claimed to be sterile by some New Zealand nurseries but Snoeijer (2004) states that it is mainly propagated by seed.
A. 'Pink Pearl'	PF	Probably an erroneous name. The single record is in Gaddum (1999a), as available from Margueritas Agapanthus, Cambridge, a nursery that no longer appears to be in business.
A. **'Platinum Pearl'** (Funnel Group)	VP: Snowcloud seedling. Stems 85–90 cm tall. Up to 170 florets per head, 60 on secondary stems. Usually 2, often 3 stems per crown. WS: (chance seedling of 'Snow Cloud'): Raised by Parva Plants, New Zealand, known since 1998.	
A. **'Platinum Pink'** (Funnel Group)	VP: Snowcloud seedling. Stems 70–90 cm tall. 90–120 florets per stem. Usually 2 stems per crown. WS: (chance seedling of 'Snow Cloud'): Raised by Parva Plants, New Zealand, known since 1998.	

***Agapanthus* species/cultivar**	**Source of record and notes**	**Comments**
A. praecox* subsp. *minimus (Lindl.) F.M.Leight.	PF [as *A. comptonii*] WS	
A. praecox* subsp. *orientalis F.M.Leight.	PF [as *A. orientalis* 'Blue' and *A. praecox* subsp. *orientalis*] PL [as *A. ori.* Blue]: Tall, blue-flowered form. WS	The typical blue-flowered *A. praecox* subsp. *orientalis*. It is likely that several named cultivars are not distinct from this form.
***A. praecox* 'Albiflorus'**	AD [as *A.* White large variety] PF [as *A. orientalis* 'White', *A. praecox* 'Alba', *A. praecox* subsp. *orientalis* 'Tall White', *A. praecox* subsp. *orientalis* 'White']. PL [as *A. ori.* White]: Tall, white flowers. RED [as *A.* 'Albus']: A white-flowered form of *A. orientalis*. WS: Known in cultivation since 1864, England, and still widely grown…as the plant was and still is seed-propagated, it is better to regard this as a group of plants that look similar rather than a proper cultivar.	Various names have been applied to the white-flowered tall-growing form of *A. praecox*.
***A.* 'Purple Cloud'** (Trumpet Group)	AD BL: Deep purple/blue [flowers]. Tall, pendulous flowers. 1.8 m. DI: One of the largest growing Agapanthus with semi-pendulous purple/violet flowers. Flowers may grow up to 1.8 m high. Grows to 1.8 m. MR: A taller grower with 1.2 m flower stems. The flowers are a rich navy blue and pendulous. PF PL: Tall violet/purp heads. Strong broad foliage. PM: Large growing mophead with broad green foliage. RED: A very robust cultivar with tall heads of semi-pendulous, violet-purple flowers to 1.8 m (6 ft). The very strong, broad foliage is tinted purple at the base. WS: (probably a hybrid between ***A. praecox* subsp. *orientalis*** and ***A. inapertus***): Introduced in New Zealand, known since 1991, and still in cultivation. Also offered as seed.	Earliest known stock was from Hugh Redgrove, from which the former Topline Nurseries in Oratia produced plants though tissue culture in the mid-1980s as a result of Japanese market demand (Barrie McKenzie, pers. comm.).

***Agapanthus* species/cultivar**	**Source of record and notes**	**Comments**
***A.* 'Purple Splendour'**	RED: Very similar to 'Purple Cloud', with slightly more rounded flower-heads. WS: Known since 1991, New Zealand…very similar to 'Purple Cloud'…	This cultivar may not be currently available in the New Zealand nursery trade.
***A.* 'Queen Anne'** (Funnel Group)	PF RED: A compact form with mid-blue flower-heads to 60 cm (24 in.). WS: Introduced in New Zealand. Known since 1990 and still in cultivation. Also offered as seed.	
***A.* 'Regal Beauty'**	PF PVR HOM124: Address for service: Lifetech Laboratories, 224 Albany Highway, Albany, Auckland, New Zealand. Breeder: R.J. & D.M.L. Wood, 226 Corbett Road, R.D.3, New Plymouth, NZ. PVR terminated: 31/7/2007. WS: Raised by R.J. and D.M.L. Wood, New Plymouth, New Zealand.	
A. 'Royal Blue' (Salver Group)	DI: Almost electric blue flowers. Always a show winner. Great in pots or borders. Will grow in a wide range of sites. HARDY. Grows to 1 m. WS: (probably a selection of *A. capanulatus*): Raised by The Crown Estate, Windsor, UK, introduced in 1974, and still in cultivation… invalid name…	Snoeijer (2004) referred to two cultivars with this name but the other cultivar is 'probably no longer in cultivation'.
***A.* 'Sarah'** (Funnel Group)	LYN: This is a first candalarbra [sic.] type *Agapanthus*. Bred by Mike Geenty at Hamilton Botanic Gardens. Flowers are a soft baby blue, marked with a deeper blue picotee. An Eco Friendly low fertility variety. Hardy. 0.6 x 0.6 m. PF PVR HOM227 [was HOM105]: Address for service: Kiwi Flora, P.O. Box 81-022, Whenuapai, Auckland, NZ. Breeder: M.F. Geenty (deceased). Expiry date (HOM227): 26/3/2029. WS: Raised by M.F. Geenty, Hamilton, New Zealand, known since 2000, and still in cultivation.	Claimed to be semi-sterile. Described in its USPTO Patent Application (http://patft.uspto.gov/netacgi/nph-Parser?Sect1=PTO1&Sect2=HITOFF&d=PALL&p=1&u=%2Fnetahtml%2FPTO%2Fsrchnum.htm&r=1&f=G&l=50&s1=PP13236.PN.&OS=PN/PP13236&RS=PN/PP13236), 'as a new and distinct *Agapanthus praecox…'*.

***Agapanthus* species/cultivar**	**Source of record and notes**	**Comments**
***A.* 'Sea Coral'**	LYN: Semi-dwarf, narrow-leafed variety. Topped from midsummer with dainty weeping white flowers that flush coral pink as the flowers age. Originally selected with the cut flower market in mind. Hardy. 0.6 x 0.6 m. PF WS: Introduced in New Zealand, known since 2000 when offered in the UK, and still in cultivation.	Raised at the Auckland Botanic Gardens and part of the Sea Series of *Agapanthus* cultivars (Jack Hobbs, pers. comm.).
***A.* 'Sea Foam'**	AD [as *A.* 'Seafoam'] DI: A smaller growing variety with pure white flower heads. Strong broad foliage. Will tolerate most soil types. HARDY. Grows to 1.2 m. PF PL [as *A.* 'Seafoam']: Large pure white 1.2 m strong broad foliage. PM: Compact white-flowering form. WS: Raised by the curator of the Botanical Garden, Auckland, New Zealand, introduced in 1998, and still in cultivation.	Raised at the Auckland Botanic Gardens and part of the Sea Series of *Agapanthus* cultivars (Jack Hobbs, pers. comm.).
***A.* 'Sea Mist'** (Funnel Group)	PF PVR HOM079: Address for service: Newplants New Zealand Ltd, 168 Metcalfe Road, Ranui, Auckland, NZ. Breeder: Auckland Regional Council, 102 Hill Road, Manurewa, Auckland, NZ. PVR terminated: 20/9/2002. WS: Raised by the curator of the Botanical Garden Auckland, New Zealand, introduced in 1998. Still in cultivation.	Raised at the Auckland Botanic Gardens and part of the Sea Series of *Agapanthus* cultivars (Jack Hobbs, pers. comm.).
***A.* 'Sea Spray'** (Funnel Group)	PF DI: An attractive prolific-flowering variety with large white flower heads in Summer. Drought tolerant. Will grow on most sites. Grows to 1.2 m. WS: Raised by the curator of the Botanical Garden, Auckland, New Zealand, introduced in 1998, and still in cultivation.	Raised at the Auckland Botanic Gardens and part of the Sea Series of *Agapanthus* cultivars (Jack Hobbs, pers. comm.).

***Agapanthus* species/cultivar**	**Source of record and notes**	**Comments**
***A.* 'Silver Baby'**	AD [as *A.* 'Silverbaby'] MR: A dwarf grower with narrow leaves. The smaller white flowers are flushed pale blue. En masse gives a silvery effect. PF PL: Dwarf free-flowering 'steely silver' selection. PM WS: Known since 2001, New Zealand…habitus dwarf.	
A. 'Small Dark' (Salver Group)	VP: Blue dwarf x patens. Stem 73 cm, slightly drawn. 45 florets. WS: ('Blue Dwarf' × ***A. campanulatus* subsp. *patens***): Raised by Parva Plants, New Zealand, known since 1998, and still in cultivation… invalid name.	One parent is possibly referable to *A.* 'Dwarf Blue'.
***A.* 'Snow Cloud'** (Funnel Group)	PF [as *A.* 'Fragrant Snow' and as *A.* 'Snowcloud']. PVR HOM067: Address for service: Lifetech Laboratories, 224 Albany Highway, Albany, Auckland, New Zealand. Breeder: V. Hooper, 19 Hutchins Street, Waitara, Taranaki, NZ. PVR terminated: 26/4/2007. VP [as *A.* 'Snowcloud']: Flower stems 90 cm, up to 1 m in semi shade, with 3–400 florets, as well as secondary stems with fewer florets all of which are scented. This is a hybrid of *A. inapertis* [sic. = ***A. inapertus*** Beauverd] and was selected to start a breeding line since it flowers very prolificly [sic.]. WS: (chance seedling of ***A. praecox* subsp. *orientalis***): Raised by V. Hooper, Waitara, Taranaki, New Zealand, known since 1997, and still in cultivation.	Trade name: *A.* 'Fragrant Snow'. Parentages stated by VP and Snoeijer (2004) disagree.

***Agapanthus* species/cultivar**	**Source of record and notes**	**Comments**
***A.* 'Snowball'** (Funnel Group)	MR: A compact grower ideally suited to borders. 40 cm stems carry balls of white flowers. PF PL: Dwarf white with tidy habit. PM PP: An excellent dwarf perennial forming attractive mounds of green with compact levels of snowball white flowers. Flowers to 30–40 cm Ideal for containers, landscaping, cut flowers, borders and rockeries. RED: A dwarf hybrid with pure white flower-heads 40–50 cm (16–20 in.) tall. WS: Introduced in New Zealand, known since 1991, and still in cultivation.	Parent stock was obtained from Hugh Redgrove by the former Topline Nurseries in Oratia who propagated it from tissue culture and introduced it on the market in the late 1980s (Barrie McKenzie, pers. comm.).
A. 'Snowdrift'	PF	The single record for this cultivar name is in Gaddum (1999a), as available from the former CH Simpson Nurseries, Nelson.
A. 'Snowdrops' (Funnel Group)	PF WS: Introduced in New Zealand. Known there since 1997, 1998 USA. Still in cultivation… invalid name.	
***A.* 'Snowstorm'** (Funnel Group)	PF PM PVR HOM050: Address for service: Plant Struck Ltd, 139 Te Puna Road, R.D.6, Tauranga, NZ. Breeder: R.W. Rother, 56 Monbulk Emerald Road, Emerald, Victoria 3782, Australia. Expiry date: 25/3/2017. WS: (chance seedling of ***A. praecox* subsp. *orientalis***): Raised by R.W. Rother, Emerald, Australia, known since 1995, and still in cultivation.	
A. 'Stormcloud'	BL [as *A.* 'Storm Cloud']: deep purple [flowers]. Tall; small head. 1.8 m. PF WS: Descriptions published under this name in the USA and New Zealand differ markedly from each other, and plants are widely raised from seed.	

***Agapanthus* species/cultivar**	**Source of record and notes**	**Comments**
***A.* 'Stormcloud Mini'** (Funnel Group)	VP: Inapertis [sic. = *A. inapertus* Beauverd] F_2 hybrid. Stems up to 100 cm semi-shade in ground, 65–70 cm potted, slightly drawn. 40–50 florets per stem. 1 stem per crown. WS: (F_2 hybrid of *A. inapertus* [?]): Raised by Parva Plants, New Zealand, known since 1998, and still in cultivation.	
***A.* 'Streamline'**	AD BL: Soft blue [flowers]. Perfect for mass planting; borders. 0.35–0.5 m. DI: A hardy blue-flowering variety. Will grow in full sun or shade. Group plantings for best display. Grows to 80 cm. LYN: This trouble-free selection never ceases to please. Neat dwarf foliage gives rise to months of sky blue flowers. Excellent for trouble-free mass planting. Hardy. 0.5 x 0.5 m. PF PL: Dwarf/med. very long flowering season. PM: An outstanding free-blooming, dwarf variety. Blue flower clusters appear in summer on long stems. Good in rockeries or amongst small shrubs. Can cope with sun to semi-shade in preferably well-drained soil. Evergreen. Hardy. Excellent for trouble-free mass planting. PP: The most floriflorus [sic.] of all the dwarf *Agapanthus*. This dwarf evergreen perennial bears clusters of sky blue trumpet-shaped flowers budding in August, flowering through summer and again in autumn. Truly a delight for any garden whether it be in massed plantings, borders, pot or containers. 50 cm. RED: (syn. *A. minor*) – An outstanding cultivar with mid-blue flowers to 60 cm. The flowers appear continuously through winter to a peak display in late spring/early summer. Foliage is narrow but dense, so it makes an excellent ground cover planted at 60 cm (24 in.) intervals. WS: Introduced by Auckland Botanical Garden, New Zealand, known since 1991…because of seed propagation, plants differ…In contrast, plants of a clone with small, 'grass-like' leaves, propagated by tissue culture, are now offered.	Propagated from a previously unnamed plant growing at the Auckland Botanic Gardens (Jack Hobbs, pers. comm.).

***Agapanthus* species/cultivar**	**Source of record and notes**	**Comments**
***A.* 'Sybil Martin'**	PVR HOM023: Breeder: D.C. Martin, c/o F.H. Bacon, 10 Selwyn Road, Havelock North, NZ. PVR terminated: 14/8/2003. WS: Raised by D.C. Martin, Havelock North, New Zealand, known since 1991.	
***A.* 'Tandice'**	PVR HOM135: Breeder: Tandarra Nurseries Ltd, 575 Gordonton Road, R.D.1, Hamilton, NZ. Application withdrawn: 4/10/2004. WS: Raised by Tandarra Nurseries Ltd, New Zealand, known since 2001.	
***A.* 'The Giant'**	PF WS: Known since 1997, New Zealand, when offered as seed.	
***A.* 'Tigerleaf'** (Variegated Leaf Group)	RED: A form of *A. orientalis* raised by Hugh Redgrove, with striking foliage, green with broad bands of yellow on each side, and blue flowers. WS: (selection of ***A. praecox* subsp. *orientalis***) Introduced by Hugh Redgrove, New Zealand. Known since 1991 and still in cultivation.	
***A.* 'Timaru'**	DI: An excellent NZ raised variety with large heads up to 20 cm in dia. Individual blooms are deep purple/blue. Grows to 1.2 m. WS: Introduced in New Zealand, known since 2001 when offered in the UK.	
***A.* 'Tinkerbell'** (Variegated Leaf Group)	AD LYN: This colourful sterile sport of **'Peter Pan'** is always popular. Who needs flowers when you have showy foliage neatly banded and edged white. Cool on the deck in a container or good for adding colour to the border. Hardy. 0.2 x 0.2 m. PF PL: Variegated green and cream. Occasional blue flower mostly sterile. 50 cm. PM: Colourful, sterile sport of **'Peter Pan'**. Showy foliage is neatly banded and edged white. Great in a container or for adding colour to a garden border. RED: A sport of **'Peter Pan'**; narrow leaves conspicuously striped with white, heads of blue flowers to 50 cm (20 in.). WS: (sport from **'Peter Pan'**) Known since 1991, New Zealand, and still in cultivation…it hardly flowers…	Claimed to be sterile or semi-sterile. Raised by Barrie McKenzie at the former Topline Nurseries in Oratia in the early 1980s (Barrie McKenzie and Bryan King, pers. comm.).

***Agapanthus* species/cultivar**	**Source of record and notes**	**Comments**
A. 'True Blue'	PF	
A. 'Variegatus'	RED [as *A.* 'Variegata']: An older variegated plant that has been slow to increase; grey-green leaves are up to 30 cm (12 in.) long, striped and bordered with white; blue flower-heads grow to 35 cm (14 in.) tall. This is a striking plant for a rock garden or the front of a border.	There are likely to be several selections under the ambiguous names 'Variegata' and 'Variegatus' – see Snoeijer (2004).
***A.* 'Wavy Navy'**	PF WS: Known since 1990 when offered as seed. Still in cultivation, offered both as seed and as plant.	
A. 'White Baby'	PF	Possibly the same as *A.* 'Dwarf White' and *A.* 'Mini White'?
***A.* 'White Christmas'** (Funnel Group)	BL: Ice white [flowers]. 1.0 m. WS: (probably a selection of *A. praecox* subsp. *orientalis*): Introduced from South Africa. Known since 1993 and still in cultivation.	
A. white dwf	PF	Probably = *A.* 'White Dwarf' which is not a valid cultivar name – see Snoeijer (2004).
***A.* 'White Ice'** (Funnel Group)	MR: A medium-sized grower. 1.2 m long, thick stems. The large flowers are pure icy white. PF PM WS: Introduced in New Zealand, known since 1997, and still in cultivation.	Introduced by the former Topline Nurseries in Oratia. It was propagated through tissue culture in the mid-1980s and first sold in the late 1980s (not 1997 as stated by Snoeijer (2004)) (Barrie McKenzie, pers. comm.).

Appendix 4 – Representative herbarium specimens of *Agapanthus* in New Zealand

4.1 New herbarium specimens from this study

Scientific name	Accession	Locality	Collection date	Collector
Agapanthus praecox subsp. *orientalis*	CHR 610033	Diamond Harbour, Banks Peninsula, Canterbury	7 Dec. 2008	D. Redmond
Agapanthus praecox subsp. *orientalis*	CHR 610034	Akaroa, Banks Peninsula, Canterbury	8 Dec. 2008	D. Redmond
Agapanthus praecox subsp. *orientalis*	CHR 610035	near the jetty at Governors Bay, Banks Peninsula, Canterbury	8 Dec. 2008	K.A. Ford
Agapanthus praecox subsp. *orientalis*	CHR 610036	Governors Bay, Banks Peninsula, Canterbury	8 Dec. 2008	K.A. Ford
Agapanthus praecox subsp. *orientalis*	CHR 610037	Princess Margaret Hospital, 95 Cashmere Road, Cashmere, Christchurch	8 Dec. 2008	K.A. Ford
Agapanthus praecox subsp. *orientalis*	CHR 610038	Avonhead, Christchurch, Canterbury	10 Dec. 2008	C. Pitcher
Agapanthus 'Finn'	CHR 610039	Oderings Nursery, Cashmere Road, Christchurch, Canterbury	5 Dec. 2008	K.A. Ford
Agapanthus 'Sarah'	CHR 610040	Lyndale Nurseries, Whenuapai, Auckland	2008	K.A. Ford
Agapanthus 'Streamline'	CHR 610041	Lyndale Nurseries, Whenuapai, Auckland	2008	K.A. Ford

4.2 Previous New Zealand herbarium specimens

Sourced from the New Zealand Virtual Herbarium (www.virtualherbarium.org.nz), locality details sourced from Allan Herbarium (CHR) and Auckland War Memorial Museum (AK) records.

AK = Auckland War Memorial Museum; CHR = The Allan Herbarium, Landcare Research; NZFRI = The New Zealand Forestry Herbarium, Scion; UNITEC = Herbarium, Unitec, Auckland; WAIK = The University of Waikato Herbarium.

Scientific name	Accession	Locality	Latitude (ºS)	Longitude (ºE)	Collection date	Collector(s)
Agapanthus	UNITEC 3268					L.R. Reid
Agapanthus	UNITEC 2288					T.M. Yungnickel
Agapanthus	AK 289229	North Island, Eastern Northland & Islands Ecological Region and District, Matapouri, side of main road (E side) to the south, c. 200m from a recycle depot	35.5	174.5	10 Jan. 2005	E.K. Cameron 12753
Agapanthus 'Dwarf White'	AK 228180	Cultivated, North Island, Auckland Ecological Region, Manukau Ecological District, Manurewa, Hill Road, Regional Botanic Gardens, African Garden	37.67	174.83	20 Feb. 1996	C.D. McCullough
Agapanthus 'Tinkerbell'	AK 229652	Cultivated, North Island, Auckland Ecological Region, Manukau Ecological District, Manurewa, Hill Road, Regional Botanic Gardens, African Garden	37.67	174.83	21 Mar. 1996	D.B. Rogan, S. McCraith
Agapanthus (blue)	CHR 522593	Kawiu Rd	40.5	175.17	7 Feb. 1980	

Scientific name	Accession	Locality	Latitude (ºS)	Longitude (ºE)	Collection date	Collector(s)
Agapanthus africanus (L.) Hoffm.	AK 149332	North Island, Hokianga County, Waipoua State Forest, Kawerua	35.5	173.33	27 Dec. 1978	A.E. Wright 2785
Agapanthus africanus (L.) Hoffm.	AK 228173	Cultivated, North Island, Auckland Ecological Region, Manukau Ecological District, Manurewa, Hill Road, Regional Botanic Gardens, African Garden	37.67	174.83	20 Feb. 1996	C.D. McCullough
Agapanthus campanulatus subsp. *patens*	AK 228172	Cultivated, North Island, Auckland Ecological Region, Manukau Ecological District, Manurewa, Hill Road, Regional Botanic Gardens, African Garden	37.67	174.83	20 Feb. 1996	C.D. McCullough
Agapanthus coddii?	AK 232421	Cultivated, North Island, Auckland Ecological Region, Tamaki Ecological District, Auckland Domain, Duck Pond area, north	36.83	174.67	2 Jan. 1996	C.D. McCullough
Agapanthus cultivar	AK 225953	Cultivated, North Island, Auckland Ecological Region, Tamaki Ecological District, Auckland Domain, formal gardens	36.83	174.67	21 Jan. 1996	C.D. McCullough
Agapanthus inapertus?	AK 291579	North Island, Auckland Ecological Region, Waitakere Ecological District, Piha dunes	36.83	174.33	23 Jan. 2004	A.M. Craw 86
Agapanthus inapertus Beauverd	AK 221730	Cultivated, North Island, Auckland Ecological Region, Tamaki Ecological District, Balmoral, 10 Thames Street	36.83	174.67	22 Jan. 1995	E.K. Cameron 8029
Agapanthus inapertus Beauverd	AK 228161	Cultivated, North Island, Auckland Ecological Region, Manukau Ecological District, Manurewa, Hill Road, Regional Botanic Gardens, African Garden	37.67	174.83	20 Feb. 1996	C.D. McCullough

Scientific name	Accession	Locality	Latitude (°S)	Longitude (°E)	Collection date	Collector(s)
Agapanthus orientalis	CHR 310649	Waikumete Cemetery, Auckland	36.83	174.5	22 Jan. 1976	S. Bowman, K. Wood, E. Bangerter
Agapanthus orientalis	CHR 474309	Auckland, Rangitoto Island, Rangitoto Wharf	36.67	174.83	30-Nov.-91	W.R. Sykes 451/91
Agapanthus orientalis	CHR 354551	Little Barrier Id: Maraeroa, Mouth of the Te Waikahare [Te Waikohare] Stream	36.17	175	7 Dec. 1978	A.E. Esler 5850; W.M. Hamilton, R. Beever and M.L. Scott
Agapanthus orientalis L.	CHR 377066	Nelson: Rocks Road			7 Dec. 1977	C. Porter 21 'Location: L'
Agapanthus orientalis Leighton	CHR 121404	south of Oamaru	45	170.83	28 Jan. 1957	A.J. Healy 57/272
Agapanthus orientalis Leighton	CHR 98648	near Oamaru	45	171	28 Jan. 1957	A.J. Healy 57/272
Agapanthus orientalis Leighton	CHR 81051	Westport, near Orowaiti Estuary	41.67	171.5	31 Jan. 1953	R. Mason (2150) & N.T. Moar
Agapanthus orientalis Leighton	CHR 88610	Granity, Buller County	41.5	171.83	9 Feb. 1953	R. Mason (2150) & N.T. Moar
Agapanthus orientalis Leighton	CHR 172738	Templeton, Canterbury	43.5	172.33	27 Jan. 1966	A.J. Healy (66/78), B.E.V. Parham
Agapanthus orientalis Leighton	CHR 511394 A	Wanganui, Wanganui, St John's Hill, 4 Brassey Road	39.83	175	28 Nov. 1996	C.C. Ogle 3148
Agapanthus orientalis Leighton	CHR 511394 B	Wanganui, Wanganui, St John's Hill, 4 Brassey Road	39.83	175	28 Nov. 1996	C.C. Ogle 3148
Agapanthus orientalis Leighton	CHR 367460	Kukumoa, Opotiki District - on Highway 2	38	177.17	Jan. 1976	M. Heginbotham
Agapanthus orientalis?	CHR 146580	Corner Robinson's & Springs Road, near Lincoln	43.5	172.33	Feb. 1967	R. Mason 10621
Agapanthus praecox cultivar	AK 232406	Cultivated, North Island, Auckland Ecological Region, Tamaki Ecological District, University of Auckland, Old Government House Grounds	36.83	174.67	3 Jan. 1996	C.D. McCullough

Scientific name	Accession	Locality	Latitude (ºS)	Longitude (ºE)	Collection date	Collector(s)
Agapanthus praecox subsp. *minimus*?	AK 301534	North Island, Wellington City	41.17	174.67	15 Jan. 2008	C. Howell
Agapanthus praecox subsp. *minimus*?	AK 301535	North Island, Wellington City	41.17	174.67	15 Jan. 2008	C. Howell
Agapanthus praecox subsp. *orientalis* Willd.	AK 291581	North Island, Auckland Ecological Region, Waitakere Ecological District, Piha			23 Jan. 2004	A.M. Craw 4
Agapanthus praecox subsp. *orientalis* Willd.	AK 295929	Chathams Ecological Region and District, Chatham (Rekohu) Island, Waitangi, Nairn Stream Mouth	43.83	-176.5	15 Feb. 2006	P.J. de Lange CH536, P.B. Heenan
Agapanthus praecox subsp. *orientalis* Willd.	AK 295928	Chathams Ecological Region and District, Chatham (Rekohu) Island, Waitangi, Nairn Stream Mouth	43.83	-176.5	15 Feb. 2006	P.J. de Lange CH536, P.B. Heenan
Agapanthus praecox subsp. *orientalis* Willd.	AK 205629	North Island, Eastern Northland and Islands Ecological Region and District, Whangaroa Harbour, above Rere Bay, track to Lane Cove Cottage	35	173.67	17 Jan. 1992	A.E. Wright 12045
Agapanthus praecox subsp. *orientalis* Willd.	AK 289837	North Island, Egmont Ecological Region and District, Mt. Egmont, west of Oakura near end of Ahuahu Road	39	173.83	19 Apr. 2005	E.K. Cameron 13082
Agapanthus praecox subsp. *orientalis Willd.*	AK 289838	North Island, Egmont Ecological Region and District, Mt. Egmont, west of Oakura near end of Ahuahu Road	39	173.83	19 Apr. 2005	E.K. Cameron 13082
Agapanthus praecox subsp. *orientalis* Willd.	AK 169248	North Island, Auckland Ecological Region, Waitakere Ecological District, Anawhata Beach	36.83	174.33	20 Dec. 1984	J. MacKinder
Agapanthus praecox subsp. *orientalis* Willd.	AK 141282	North Island, Auckland Ecological Region, Waitakere Ecological District, Bethells Beach, roadside near beach	36.83	174.33	6 Feb. 1977	A.E. Wright 1874

Scientific name	Accession	Locality	Latitude (°S)	Longitude (°E)	Collection date	Collector(s)
Agapanthus praecox subsp. *orientalis* Willd.	AK 280174	North Island, Auckland Ecological Region, Waitakere Ecological District, south Piha, near start of Tasman Lookout Track	36.33	174.33	16 Dec. 2002	E.K. Cameron 11332a
Agapanthus praecox subsp. *orientalis* Willd.	AK 291577	North Island, Auckland Ecological Region, Waitakere Ecological District, Piha dunes	36.83	174.33	23 Jan. 2004	A.M. Craw 6
Agapanthus praecox subsp. *orientalis* Willd.	AK 291580	North Island, Auckland Ecological Region, Waitakere Ecological District, Piha, beach front garden	36.83	174.33	23 Jan. 2004	A.M. Craw
Agapanthus praecox subsp. *orientalis* Willd.	AK 291582	North Island, Auckland Ecological Region, Waitakere Ecological District, Piha Road, c. 1 km up the hill from Glen Esk Road	36.83	174.33	23 Jan. 2004	A.M. Craw 118
Agapanthus praecox subsp. *orientalis* Willd.	AK 251746	North Island, Auckland Ecological Region, Tamaki Ecological District, Glen Eden, Waikumete Cemetery, 'flower sanctuary'	36.83	174.5	11 Dec. 2000	E.K. Cameron 10337
Agapanthus praecox subsp. *orientalis Willd.*	AK 289253	North Island, Eastern Northland & Islands Ecological Region and District, west of Whangaumu Bay	35.5	174.5	12 Dec. 2005	E.K. Cameron 12769
Agapanthus praecox subsp. *orientalis* Willd.	AK 256409	North Island, Auckland Ecological Region, Tamaki Ecological District, Orakei, opposite 56 Paritai Drive, Council land	36.83	174.67	17 Apr. 2002	E.K. Cameron 11056
Agapanthus praecox subsp. *orientalis* Willd.	AK 277286	Auckland, Rangitoto Island, Yankee Wharf track, c. 50 m from Islington Bay end of foot track	36.67	174.83	21 Dec. 1987	A. Julian

Scientific name	Accession	Locality	Latitude (°S)	Longitude (°E)	Collection date	Collector(s)
Agapanthus praecox subsp. *orientalis* Willd.	AK 284018	North Island, Coromandel Ecological Region, Great Barrier Ecological District, Great Barrier Island, Whangaparapara, adjacent to road between lodge and wharf	36.17	175.33	1 Nov. 2002	T.J. Martin 303
Agapanthus praecox subsp. *orientalis* Willd.	AK 284620	North Island, Coromandel Ecological Region, Colville Ecological District, north Waikawau Bay, estuary margin	36.5	175.5	23 Dec. 2003	E.K. Cameron 12065
Agapanthus praecox subsp. *orientalis* Willd.	AK 284621	North Island, Coromandel Ecological Region, Colville Ecological District, north Waikawau Bay, estuary margin	36.5	175.5	23 Dec. 2003	E.K. Cameron 12065
Agapanthus praecox subsp. *orientalis* Willd.	AK 294836	North Island, Whakatane Ecological Region, Te Teko Ecological District, Whakatane, back of main town	37.83	176.83	24 Dec. 2005	E.K. Cameron 13261
Agapanthus praecox subsp. *praecox* Willd.	AK 291578	North Island, Auckland Ecological Region, Waitakere Ecological District, Piha dunes	36.83	174.33	23 Jan. 2004	A.M. Craw 2
Agapanthus praecox subsp. *praecox* Willd.	AK 218779	North Island, Auckland Ecological Region, Tamaki Ecological District, Avondale, on coast west of Patiki Road	36.83	174.67	29 Apr. 1993	R.O. Gardner 6953
Agapanthus praecox subsp. *orientalis* (Leighton) Leighton	CHR 480246 A	North Auckland, Near Warkworth, Kawau Island, near Lady's Bay	36.33	174.67	30 Nov. 1992	W.R. Sykes 329/92
Agapan*thus praecox* subsp. *orientalis* (Leighton) Leighton	CHR 480246 B	North Auckland, Near Warkworth, Kawau Island, near Lady's Bay	36.33	174.67	30 Nov. 1992	W.R. Sykes 329/92
Agapanthus praecox subsp. *orientalis* (Leighton) Leighton	CHR 480246 C	North Auckland, Near Warkworth, Kawau Island, near Lady's Bay	36.33	174.67	30 Nov. 1992	W.R. Sykes 329/92
Agapanthus praecox subsp. *orientalis*	NZFRI 18657		38	176		C.E. Ecroyd 15190

Scientific name	Accession	Locality	Latitude (°S)	Longitude (°E)	Collection date	Collector(s)
Agapanthus praecox subsp. *orientalis*	NZFRI 27256		37	177		S.J. Crump 72846, P.B. Cashmore, J.F.F. Hobbs
Agapanthus praecox Willd.	AK 301886	North Island, Auckland Ecological Region, Inner Gulf Islands Ecological District, Tiritiri Matangi Island, behind Visitors Centre	36.5	174.83	15 Dec. 2007	N.C. Davies
Agapanthus praecox Willd. subsp. *orientalis* (Leigh.) Leigh.	WAIK 15392		36.67	175.17		B. Ryburn
Agapanthus praecox Willd. subsp. *orientalis* (Leigh.) Leigh.	WAIK 18929		37.83	175.33		Julia Marmont
Agapanthus praecox subsp. *orientalis*	NZFRI 1530					28555
Agapanthus praecox subsp. *orientalis*	NZFRI 26486		37.67	177.67		28555
Agapanthus praecox subsp. *orientalis*	AK 311991	North Island, Auckland Region, Inner Gulf Islands, Kawau Island, SE of Lady's Bay			11 Apr. 2010	E.K. Cameron 15438