Te Uru Rākau New Zealand Forest Service

Acceleration of Primary production in Native Trees.

A report on the results of Sub-Projects 2, 4, 5, 6, 7 and 8.

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Executive summary

This report outlines the findings of Scion's research aimed at accelerating New Zealand's native tree nursery production capacity and increasing establishment success. To achieve this, we addressed several issues relating to native tree establishment and plant propagation across six projects, as part of a wider 8-phase project for the One Billion Trees (1BT) programme.

This research has advanced our knowledge, expertise and use of technology in the native tree nursery sector. Consequently, we have developed plant quality parameters and recommendations in conjunction with native tree establishment stakeholders and industry. These outcomes are relevant to native tree nurseries and future industry partners and will help increase the propagation and capacity of native trees to assist in meeting the goals of the 1BT programme.

In Project 2, we investigated the effect of different container types on nursery plant quality. While nursery survival was good across most container types, based on a media cost perspective, grow-bags appear to have a production cost advantage. However, investigation of infrastructure and environmental costs should be addressed in future studies. In Project 4, we aimed to test the impact of improved environmental control on grow-out times and quality of native tree species. Results showed that plants grown with environmental controls had greater survival and a longer seedling production window. Polyhouses may also assist in enhancing growth and survival of native trees in the nursery. In Project 5, we explored different media and fertiliser combinations for different native species to generate recommendations and optimise plant health and establishment success. It was found that different combinations of media mixes can influence plant growth, with most native species in this study growing faster and developing more robust root collar diameters with increasing nutrient availability. These findings can be used by nurseries to improve their own growing media.

The use of automated, low-labour systems is commonly used in exotic commercial crops and has potential to be used for native nurseries. In Project 6, we tested the viability of automated propagation technologies for native species production. It was found that the use of automation could improve nursery space utilisation, reduces growing costs and improves transport efficiency. However, ongoing research is still required and will depend on the goal of individual nurseries.

Seed production and supply are highly variable between seasons in many New Zealand native plants and mini-hedges can improve cuttings. In Project 7, we aimed to explore the suitability of mini-hedge cutting technique in native species. While mini-hedges showed good potential for cuttings in particular species (*Podocarpus totara* and *Metrosideros excelsa*), success varied widely across other species and more research is needed to explore this further.

A key aim of these projects is to ensure that outcomes of this research will be made available to the industry at large, including native plant and forestry nurseries. In Project 8, the results from subsequent projects were discussed with key stakeholders in a workshop hosted at Scion, to produce best practice guidelines and recommendations for plant quality specifications. This is a significant step forward and may be used by nurseries as a benchmark for their own plant production.

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Introduction

To meet the goals of the One Billion Trees (1BT) programme, there needs to be an acceleration in the deployment of high-quality native trees across New Zealand. By increasing the efficiency of tree production and diversity of native tree species, this can increase productivity, carbon sequestration and innovation in forestry and related sectors.

The wider 8-phase project for the 1BT programme aims to demonstrate how the New Zealand nursery sector can directly increase native tree production and establishment success, thereby increasing the annual supply into the marketplace.

To achieve this, we aimed to address:

1. Limitations imposed through a slow production cycle for native trees, by identifying taxa suitable for production using a containerized forestry crop system.

2. Alternative, faster growing systems for slower growing native species that are not suited to forestry crop systems. We will also test and recommend growing media for native tree species to reduce production time.

3. Limitations for seed collections, including access, logistics and cost, by improving seed germination protocols for native tree species. We will also explore supplementing native tree seedling supply with cuttings by using a mini-hedge system for mother stock.

4. Tree establishment issues relating to plant quality, by proposing a plant quality system based on our existing research and knowledge, with refinement through industry workshopping.

5. Nursery productivity and efficiency, by exploring the use of enclosed grow-out tunnels and mechanisation to improve health and accelerate production bottlenecks.

This research will improve our knowledge, expertise and technology in the native tree nursery sector, leading to improved propagation techniques and technologies for scaled-up and more efficient production of diverse tree species. Both nurseries and future industry partners will benefit from easier, faster and cheaper establishment and improved operating efficiencies. These findings will also be significant for industries which are challenged with labour issues. Furthermore, by reducing the amount of plastic destined for landfill, this may have significant advantages to the environment and nurseries that require long term social licences to operate.

This report outlines 6 projects (Projects 2,4,5,6,7 and 8) which are part of a wider research programme spanning 8 key components of propagation. These are outlined in Table 1.1.

The outcomes of this research will be made available to the industry at large, including native plant and forestry nurseries. This will be though published reports, talks and workshops delivered at Scion and through Forest Growers Research Inc and New Zealand Plant Producers Incorporated (NZPPI). Our Strategic collaboration partners include:

- New Zealand Plant Producers Incorporated (NZPPI)
- Rotorua Lakes council
- Bay of Plenty regional council
- Ellepot, Denmark
- Scion Nursery, Rotorua
- Treeline Native Nursery, Rotorua

- Minginui Nursery, Minginui
- Tipu Wai Trust.

Table 1.1: The eight projects undertaken to improve the propagation success of native plants.

Project	Description
1. Seed germination protocols for native tree species[1]	Research and testing of seed pre-treatment and germination techniques for native tree taxa.
2. Container type - nursery trial	Trial the suitability of an alternative container types to the current industry standard in improving deployment of native trees.
2.1 Identification of species suitable for production in a containerised forestry crop system.	Testing propagation and establishment success of fast-growing native tree species raised in Forestry system (forestry tray and paper pot) vs current standard practice (PB2 bags).
2.2 Alternative growing systems for slower growing native species.	Testing the propagation and establishment success of slower growing native trees species raised in 1L 'jumbo' paper pots vs current SOP (PB2 bags).
3. Field testing of forestry and alternative container types for native tree species[2]	Testing field establishment success and growth of native tree species raised in Forestry trays and alternative systems.
4. Using enclosed grow-out tunnels to improve health and accelerate deployment of native trees.	Test the impact of improved environmental control, though enclosed greenhouses, on the grow out times, and quality, of native tree species.
5. Revision of growing media requirements/recommendations for native tree species.	Testing media and fertiliser combinations for growing native tree species.
6. Mechanisation to address production bottlenecks.	Trial the suitability of an automated sowing and potting machines for native tree production.
6.1 Mechanised, direct, sowing of native seed	Improve nursery efficiency by automating sowing in the nursery, thereby replacing the need for 'pricking-out'.
6.2 Mechanised production of large growing containers	Test an alternative, automated, process to replace manual filling of potting bags.
7. Supplementing native tree seedling supply with cuttings using a mini-hedge system for mother stock.	Testing of suitability of native tree taxa for establishment via mini-cuttings.
8. Plant quality system.	Provision of industry standards for plant quality.

[1] Results can be found in a separate report found HERE
[2] Results can be found in a separate report found HERE

Project 2: Container type – nursery trial



BACKGROUND

Increasing the production capacity of New Zealand's native tree nursery sector is crucial for the development of native species production forestry. This can lead to enhanced establishment success and annual supply into the marketplace. However, current industry standard practices for plant production have high demand on resources such as media, water, space limitations, transportation, and planting. This project was designed to investigate suitable container type alternatives to the current industry standard for raising native species. By testing alternative container types (such as paper pots and forestry grade trays) this could identify evidence-based alternatives which could substantially reduce costs associated with plant production and increase the nursery production capacity.

This section of the report relates to Project 2 (Table 1.1) as part of a wider research programme spanning 8 key components of propagation.

Objectives

The objectives of this project were to investigate the potential to produce native trees in the nursery more rapidly while using less resources (media, space, and labour).

Aims

1. Determine the suitability of various container types, of varying sizes, for pricking-out of native seedlings.
2. Determine the suitability of various container types, of varying sizes, for potting-up of native seedlings.
3. Test the propagation success of fast-growing native tree species raised in the standard forestry system (forestry tray and paper pot) vs current standard practice (PB2 bags).
4. Test the propagation success of slower growing native trees species raised in 'jumbo' paper pots vs current standard practice (PB2 bags).

MATERIALS AND METHODS

Treatments

Thirty-one species were raised in the Scion nursery for this project (Table 2.1).

Table 2.1: Species sown in Project 2.

Species name	Common name
Agathis australis	Kauri
Alectryon excelsus	Titoki
Aristotelia serrata	Makomako / Wineberry
Beilschmiedia tawa	Tawa
Coprosma grandifolia	Kanono
Coprosma robusta	Karamu
Cordyline australis	Tī kōuka / Cabbage Tree
Corynocarpus laevigatus	Karaka
Dacrycarpus dacrydioides	Kahikatea
Dacrydium cupressinum	Rimu
Dodonaea viscosa	Ake-ake
Elaeocarpus dentatus	Hīnau
Hoheria angustifolia	Narrow-leaved lacebark
Knightia excelsa	Rewarewa
Kunzea ericoides	Kānuka
Leptospermum scoparium	Mānuka
Lophozonia menziesii	Tawhai / Silver beech
Melicytus ramiflorus	Mahoe / Whiteywood
Metrosideros excelsa	Pohutukawa
Phyllocladus trichomanoides	Tanekaha
Pittosporum crassifolium	Karo
Plagianthus regius	Manatu / Ribbonwood
Podocarpus totara	Tōtara
Prumnopitys ferruginea	Miro
Pseudopanax arboreus	Puahou / Punahou / Five finger
Pseudopanax crassifolius	Lancewood
Pseudopanax arboreus X Pseudopanax crassifolius	Hybrid- Five Finger and Lancewood
Sophora microphylla	Kōwhai (microphylla)
Sophora tetraptera	Kōwhai
Vitex lucens	Pūriri
Weinmannia racemosa	Kamahi

Trial design

A split plot design was used where the main-plot was the species, the sub-plot was the pricking-out container type and the sub-sub plot was the potting-on container type.

Eleven different container types were used in this project, where small seedlings were pricked-out from germination trays into a range of different container types (Table 2.2).

Table 2.2: Container types and sizes used for pricking out into a range of different container types.

Container type	Container volume
3.5cm paper pots	90ml
TS45	90ml
BCC V90	90ml
TS48	125ml
4.0cm paper pots	125ml
BCC V150	150ml
Root trainers (Hilson)	172ml
BCC V310	300ml
Root trainers (Tinus)	352ml
T28 trays	500ml
8.0cm paper pots	700ml

Two different larger container types were used when potting-up smaller seedlings into larger containers (Table 2.3).

Table 2.3: Container types and sizes used to pot up into for the container trial.

Container type	Container volume
10.0cm paper pot	900ml
PB2 bag	1200ml

Methodology

1. Trial germination was carried out at the Scion Research Nursery.
2. All available seed of the 31 species (Table 2.1) were sown into germination trays.
3. Once at a suitable height of approximately 2cm, germinants were transplanted ("pricked-out") into the eleven containers available (Table 2.2). Pricking-out took place at Scion Research nursery and Treeline Native nursery.
4. All containers at both nurseries used the same growing media, a tailored mix from a commercial media supplier.
5. Once at a suitable size, pricking out containers 1-5 were used to pot-up, with 1/3 of plants staying in their original tray, 1/3 being potted into 10cm paper pots and 1/3 planted into PB2 bags (Table 2.3).
6. All combinations available were assessed for nursery plant quality (survival, height and root collar diameter (RCD)) in April 2020, before they were dispatched for planting in the field.

RESULTS

Germination and pricking-out process

By the end of November 2019, 17 species had been successfully germinated and transplanted into their growing containers (Table 2.4). Six species had started to germinate but were not yet ready for transplant and eight species had not yet germinated.

Table 2.4: Species germination and pricking-out progress at the end of November 2019.

Species name	Common name	Germinated	Pricked-out
Aristotelia serrata	Makomako / Wineberry	Y	Y
Beilschmiedia tawa	Tawa	Y	Y
Coprosma grandifolia	Kanono	Y	Y
Coprosma robusta	Karamu	Y	Y
Cordyline australis	Tī kōuka / Cabbage Tree	Y	Y
Corynocarpus laevigatus	Karaka	Y	Y
Dacrycarpus dacrydioides	Kahikatea	Y	Y
Dodonaea viscosa	Ake-ake	Y	Y
Hoheria angustifolia	Narrow-leaved lacebark	Y	Y
Kunzea ericoides	Kānuka	Y	Y
Leptospermum scoparium	Mānuka	Y	Y
Melicytus ramiflorus	Mahoe / Whiteywood	Y	Y
Metrosideros excelsa	Pohutukawa	Y	Y
Plagianthus regius	Manatu / Ribbonwood	Y	Y
Pseudopanax crassifolius	Lancewood	Y	Y
Pseudopanax crassifolius hybrid	Lancewood hybrid	Y	Y
Vitex lucens	Pūriri	Y	Y
Agathis australis	Kauri	Y	N
Alectryon excelsus	Titoki	Y	N
Elaeocarpus dentatus	Hīnau	Y	N
Lophozonia menziesii	Tawhai / Silver beech	Y	N
Podocarpus totara	Tōtara	Y	N
Sophora microphylla	Kōwhai (microphylla)	Y	N
Dacrydium cupressinum	Rimu	N	N
Knightia excelsa	Rewarewa	N	N
Phyllocladus trichomanoides	Tanekaha	N	N
Pittosporum crassifolium	Karo	N	N
Prumnopitys ferruginea	Miro	N	N
Pseudopanax arboreus	Puahou / Punahou / Five finger	N	N
Sophora tetraptera	Kōwhai	N	N
Weinmannia racemosa	Kamahi	N	N

In the germination column, Y indicates species that had germinated and N indicates species that had not germinated. In the pricked-out column, Y indicates germinants that were pricked-out into their containers and N indicates germinants that had not been pricked-out.

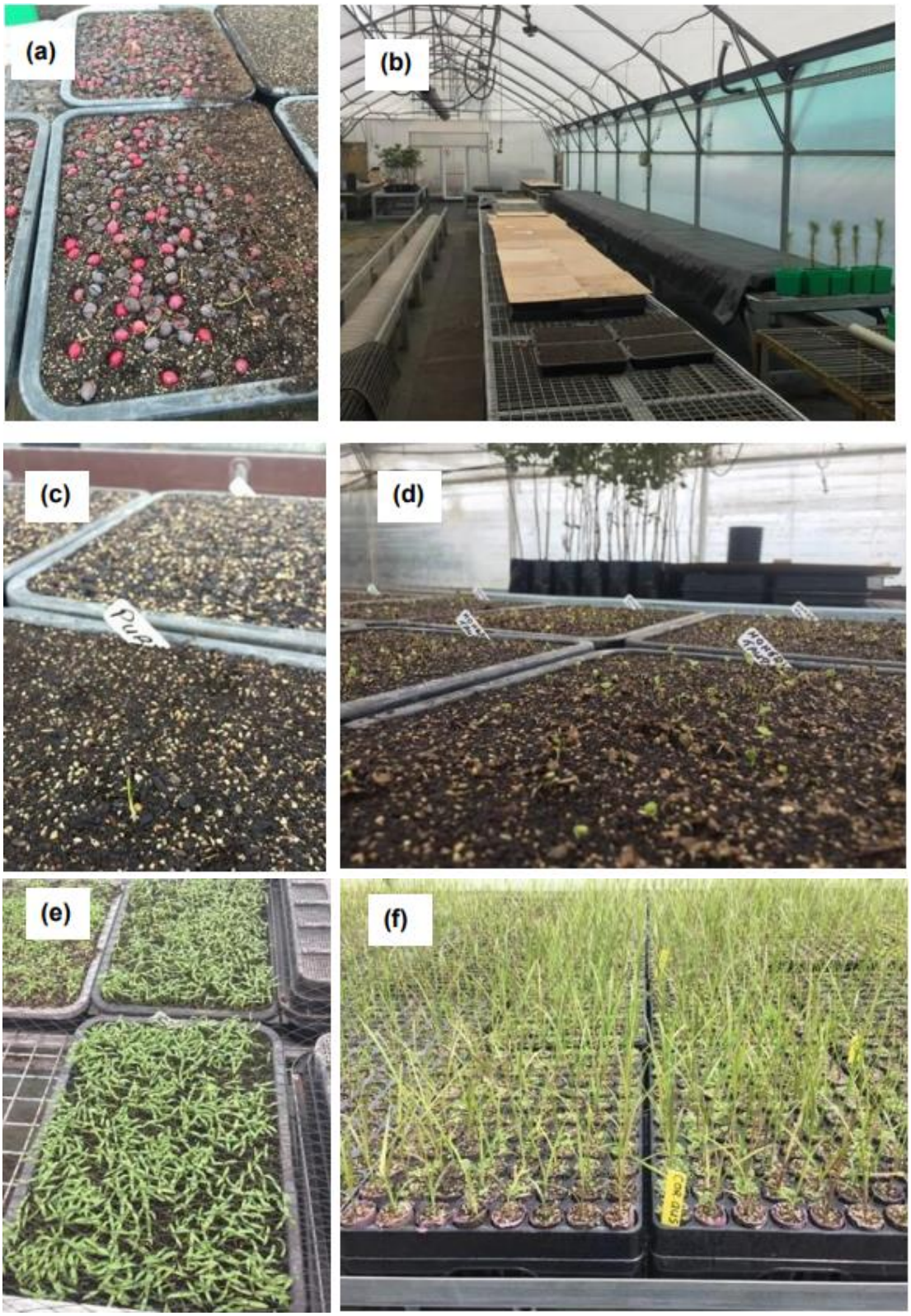

Figure 2.1: Initiation of Project 2 container type trial. (a) Sowing *Prumnopitys ferruginea* into germination trays. (b) All germination trays sown and under cover inside Scion's polyhouse for germination. (c) First trial germinant was a *Vitex lucens* seedling. (d) Good start to germination in *Hoheria angustifolia*. (e) *Dodonaea viscosa* ready for transplanting into their next containers. (f) *Cordyline australis* pricked-out into 3.5cm paper pots.

By the end of December 2019, 22 species had been successfully germinated and had been pricked-out into their growing containers (Figure 2.1; Table 2.5). Two species had just started to germinate. *Agathis australis* had germinated but survival was poor and so it was not potted-on. Six species had not yet germinated. Eleven of the species were transplanted (potted-up) during December 2019 and the remaining species were potted-up during January 2020. Seeds of *Corynocarpus laevigatus* were large and so were sown directly into PB2, 10cm paper pots and 8cm paper pots (Figure 2.3).



Figure 2.2: Plants ready for transplant into large volume containers (10cm paper pots and PB2 bags). (a) *Hoheria angustifolia* in a 3.5cm paper pot. (b) *Cordyline australis* in a 4cm paperpot.

Table 2.5: Species germination, pricking out and potting-up progress at the end of December 2019.

Species name	Common name	Germinated	Pricked-out	Potted-up	Comment
Aristotelia serrata	Makomako / Wineberry	Y	Y	Y	
Beilschmiedia tawa	Tawa	Y	Y	Y	
Coprosma robusta	Karamu	Y	Y	Y	
Cordyline australis	Tī kōuka / Cabbage Tree	Y	Y	Y	
Corynocarpus laevigatus	Karaka	Y	Y	Y	
Dodonaea viscosa	Ake-ake	Y	Y	Y	
Hoheria angustifolia	Narrow-leaved lacebark	Y	Y	Y	
Kunzea ericoides	Kānuka	Y	Y	Y	
Leptospermum scoparium	Mānuka	Y	Y	Y	
Melicytus ramiflorus	Mahoe / Whiteywood	Y	Y	Y	
Plagianthus regius	Manatu / Ribbonwood	Y	Y	Y	
Coprosma grandifolia	Kanono	Y	Y		
Dacrycarpus dacrydioides	Kahikatea	Y	Y		
Metrosideros excelsa	Pohutukawa	Y	Y		
Pseudopanax crassifolius	Lancewood	Y	Y		
Pseudopanax hybrid	Lancewood hybrid	Y	Y		
Vitex lucens	Pūriri	Y	Y		
Alectryon excelsus	Titoki	Y	N		
Elaeocarpus dentatus	Hīnau	Y	N		
Lophozonia menziesii	Tawhai / Silver beech	Y	N		
Podocarpus totara	Tōtara	Y	N		
Sophora microphylla	Kōwhai (microphylla)	Y	N		
Pseudopanax arboreus	Puahou / Punahou / Five finger	Y	N		Late germination
Sophora tetraptera	Kōwhai	Y	N		Late germination
Agathis australis	Kauri	Y	N		Too few germinated
Dacrydium cupressinum	Rimu	N	N		
Knightia excelsa	Rewarewa	N	N		
Phyllocladus trichomanoides	Tanekaha	N	N		
Pittosporum crassifolium	Karo	N	N		
Prumnopitys ferruginea	Miro	N	N		
Weinmannia racemosa	Kamahi	N	N		

In the germination column, Y indicates species that had germinated and N indicates species that had not germinated. In the pricked-out column, Y indicates germinants that were pricked-out into their containers and N indicates germinants that had not been pricked-out. In the potted-up column, Y indicates species that were potted-up.



Figure 2.3: Seedlings of *Corynocarpus laevigatus* (Karaka). Due to their large seed, they were directly sown into PB2, 10cm paper pots and 8cm paper pots (left to right).

Nursery plant quality

In April 2020, the growth in height and RCD were measured across different containers as indicators of plant quality (Tables 2.6 and 2.7, respectively). Only species with enough stock to generate statistically significant fields trial results were included in these measurements (18 species). A complete list of the comparison among species, initial container, and final container and survival combination results are shown in Appendix 1.

Table 2.6: Average heights (cm) of tree species in each container volume and type prior to dispatch in the field, completed in April 2020.

Species	Common name	3.5cm paper pots – 90ml	Hiko V90 – 90ml	TS45 – 90ml	4.0cm paper pots – 125ml	TS48 – 125ml	Hiko V150	Hiko V310	T28	8cm grow bag	10cm grow bag	PB2	Average
Dodonaea viscosa	Ake-ake	36.8	55.3	48.5	48.8	50.7	36.6	83.6	111.9	105.4	83.4	107.5	**72.1**
Cordyline australis	Tī kōuka / Cabbage Tree	34.3	34.8	31.6	38.3	32.8	34.5	42.0	53.0	61.7	47.6	57.7	**46**
Pseudopanax arboreus	Five finger				16.6								**16.6**
Pseudopanax crassifolium hybrid	Lancewood/ Five finger hybrid	10.2			16.5	9.8	16.1	23.3		23.2	22.9	23.5	**20.1**
Hoheria angustifolia	Narrow-leaved lacebark	58.7		64.1	70.8	63.9	65.1	84.4	101.5	109.3	109.0	117.7	**92.7**
Coprosma grandifolia	Kanono	17.0	24.3	22.9	25	20.4	28.9	36.2	35.6	40	25.4	26.9	**25.7**
Kunzea ericoides	Kānuka	56.4	64.4	68.3	69.4	71.3	77.3	94.9	96.3	99.5	89.9	98.1	**85.2**
Coprosma robusta	Karamu	45.4	56.1	64.9	49.5	45.8	33.5	70.0	91.6	84.9	81.1	84	**69.4**
Sophora microphylla	Kōwhai (microphylla)	34.3		35.1	37.0	43.8	41.1	42.7	49.6	41.0	43.9	43.7	**40.6**
Pseudopanax crassifolius	Lancewood	9.3			21.6	11.5	17.9	30.0	31.0	27.5	29.9	33.7	**27.5**
Melicytus ramiflorus	Mahoe / Whiteywood	24.4	29.0	28.4	26.2	30.1	23.0	34.5	59.7	61.0	43.6	53.9	**41.7**
Leptospermum scoparium	Mānuka	69.6	81.8	74.5	80.3	79.6	99.7	91.9	95.0	102.1	98.8	103.5	**92.7**
Metrosideros excelsa	Pohutukawa	24.1	13.1	12.7	38.2	33.4	14.6	25.5		28.8	28.9	26.4	**31.2**
Vitex lucens	Pūriri			21.2	14.5			19.5	34.0	32.0	27.3	36.9	**26.8**
Plagianthus regius	Manatu / Ribbonwood	65.7	66.0	66.4	71.7	71.4	76.6	87.0	97.4	97.1	90.3	100.4	**78.8**
Lophozonia menziesii	Tawhai / Silver beech				21.0				28.3	19.3	18.8	20.2	**20.7**
Podocarpus totara	Tōtara	26.8	24.3	21.1	25.8	25.3	26.8	29.8	40.6	33.8	25.4	30.3	**28.1**
Aristotelia serrata	Makomako / Wineberry	55.1	64.0	67.2	80.5	63.4	67.5	73.4	122.1	110.8	101.6	109.3	**82.1**
	Average	**44.8**	**52.8**	**53.2**	**46.1**	**50.3**	**50.0**	**65.2**	**81.5**	**84.5**	**71.7**	**79.9**	**64.8**

Table 2.7: Average root collar diameter (RCD) (mm) of tree species in each container volume and type prior to dispatch in the field, completed in April 2020.

Species	Common name	3.5cm paper pots – 90ml	Hiko V90 – 90ml	TS45 – 90ml	4.0cm paper pots – 125ml	TS48 – 125ml	Hiko V150	Hiko V310	T28	8cm grow bag	10cm grow bag	PB2	Average
Dodonaea viscosa	Ake-ake	3.1	4.4	3.8	4.2	4.2	5.5	5.8	7.5	9.4	8.5	10.3	**6.2**
Cordyline australis	Tī kōuka / Cabbage Tree	13.3	12.5	11.3	14.4	12.5	13.0	18.6	21.6	28.9	26.1	31.0	**21.3**
Pseudopanax arboreus	Five finger				4.3								**4.3**
Pseudopanax crassifolium hybrid	Lancewood/ Five finger hybrid	3.7			4.4	4.1	5.0	4.8		5.7	5.9	6.5	**5.4**
Hoheria angustifolia	Narrow-leaved lacebark	5.1		4.4	5.5	4.6	5.2	6.2	8.0	10.1	10.1	11.6	**8.1**
Coprosma grandifolia	Kanono	3.7	4.1	5.0	3.7	4.6	4.9	6.5	7.3	7.3	5.6	6.7	**4.8**
Kunzea ericoides	Kānuka	3.8	3.9	4.8	4.1	4.0	4.7	6.3	6.9	8.1	7.1	8.3	**6.3**
Coprosma robusta	Karamu	5.4	5.4	5.4	5.9	5.9	7.1	8.4	9.7	13.9	12.3	13.1	**9.6**
Sophora microphylla	Kōwhai (microphylla)	3.8		4.7	4.4	3.8	4.1	6.7	5.3	5.2	5.1	5.6	**5.0**
Pseudopanax crassifolius	Lancewood	4.0			4.4	4.9	5.3	6.5	6.3	6.1	6.6	7.5	**6.3**
Melicytus ramiflorus	Mahoe / Whiteywood	4.8	6.1	5.4	5.8	6.4	7.7	8.3	11.3	15.3	14.7	15.4	**10.9**
Leptospermum scoparium	Mānuka	4.0	4.0	3.8	4.0	4.0	4.7	5.9	6.1	8.3	7.6	8.3	**6.4**
Metrosideros excelsa	Pohutukawa	4.5	4.0	3.2	4.7	4.5	4.2	5.5		7.1	8.7	8.9	**4.8**
Vitex lucens	Pūriri			4.7	5.0			5.7	7.9	9.6	7.7	9.2	**7.2**
Plagianthus regius	Manatu / Ribbonwood	5.4	4.2	5.3	5.2	5.7	6.3	7.1	8.5	10.3	8.7	9.7	**6.6**
Lophozonia menziesii	Tawhai / Silver beech				3.2				4.6	3.8	5.2	5.4	**4.6**
Podocarpus totara	Tōtara	2.5	2.4	2.0	2.5	2.6	2.9	2.9	4.0	3.8	2.8	3.1	**2.9**
Aristotelia serrata	Makomako / Wineberry	4.4	4.4	4.4	5.3	5.0	5.8	7.8	10.2	12.9	9.1	9.3	**7.0**
	Average	**5.4**	**5.6**	**5.3**	**4.7**	**5.4**	**6.6**	**7.6**	**9.4**	**12.2**	**11.0**	**12.2**	**8.5**

DISCUSSION AND CONCLUSIONS

Nursery survival was good across all container types (see Appendix 1), with a reasonably consistent survival above 90% in all but three species (*Meterosideros excelsa*, *Beilschmiedia tawa* and *Lophozonia menziesii*).

Larger pots grew plants with larger RCDs and heights. The average height across all species was greatest in the 8cm paper pot (grow bag). The average RCD across all species was greatest in the 8cm and 10cm grow bags and the PB2 containers.

A larger grow bag appeared to grow an equivalent sized plant to a PB2. The average media in the grow bags was smaller, for example a 10cm diameter paper pot contained 700mm^3 of media c.f. compared to 1000mm^3 for a PB2. Therefore, from a pure media cost perspective, for growing larger plants, grow bags appear to have a production cost advantage. However, this does not take into account infrastructure costs or the cost of plastic to the environment.

Project 4: Using enclosed grow out tunnels to improve health and on-time deployment of native trees



BACKGROUND

Plant quality and health and attrition across the production cycle of native plants remains an issue for large-scale production. This can lead to poor quality plants, or even expensive plant production cycles that are passed on to the customer. This project was designed to test the use of enclosed grow-out tunnels with a controlled environment using a range of native species. The results from this study may assist in the optimisation of the growth and survival of native trees within the nursery to increase the production capacity of the native tree sector.

This section of the report relates to Project 4 (Table 1.1) as part of a wider research programme spanning 8 key components of propagation.

Objectives

1. To develop methods that might optimise growth and survival of native trees in the nursery, thereby producing more native trees
2. Widen the seedling production window of native trees, thus improving nursery production efficiencies.

Aim

To test the impact of improved environmental control, though enclosed greenhouses, on the grow-out times, and quality, of native tree species.

Materials and methods

Treatments

A total of ten species were sown for use in this project (Table 3.1). Two different growing environments were used: open-grown out tables and enclosed grown-out tables (polyhouse). Plant quality was measured by plant height and RCD.

Table 3.1: Species sown for Project 4.

Species name	Common name
Aristotelia serrata	Makomako / Wineberry
Coprosma robusta	Karamu
Cordyline australis	Tī kōuka / Cabbage Tree
Hoheria angustifolia	Narrow-leaved lacebark
Kunzea ericoides	Kānuka
Leptospermum scoparium	Mānuka
Melicytus ramiflorus	Mahoe / Whiteywood
Metrosideros excelsa	Pohutukawa
Plagianthus regius	Manatu / Ribbonwood
Podocarpus totara	Tōtara

Trial design

A split plot design was used, where the main-plot was the growing environment and the sub-plot was the species. Five replications were used and analysed with ANOVA.

Methodology

1. In December 2019, eight trays of each of the trial species were pricked-out into a low fertiliser mix in TS48 trays and given time to establish.
2. During February 2020, seedlings were measured. During March 2020 they were transferred to their growing out area treatments (open-grow out or polyhouse) ahead of the winter growing season. The trays in both environments received equal fertigation.
3. Plant mortality and growth were assessed in July 2020.

RESULTS

Measurements of plant heights at transfer (February 2020)

The starting heights were reasonably consistent between different growing conditions for all plant species (Table 3.2, Figure 3.1). These measurements were used as baseline heights, to determine differences in growth increment under the two growing conditions at a later timepoint.

Table 3.2: Average starting heights (cm) for each treatment and species.

Species name	Common name	Open grow-out	Polyhouse	Average
Aristotelia serrata	Makomako / Wineberry	14.2	14.3	14.2
Coprosma robusta	Karamu	10.3	9.8	10.0
Cordyline australis	Tī kōuka / Cabbage Tree	15.3	18.0	16.6
Hoheria angustifolia	Narrow-leaved lacebark	32.6	32.0	32.3
Kunzea ericoides	Kānuka	12.5	11.8	12.1
Leptospermum scoparium	Mānuka	25.2	29.8	27.5
Melicytus ramiflorus	Mahoe / Whiteywood	4.4	4.4	4.4
Metrosideros excelsa	Pohutukawa	3.8	3.1	3.5
Plagianthus regius	Manatu / Ribbonwood	22.2	22.6	22.4
Podocarpus totara	Tōtara	3.3	3.8	3.5
	Average	**13.9**	**14.2**	**14.6**

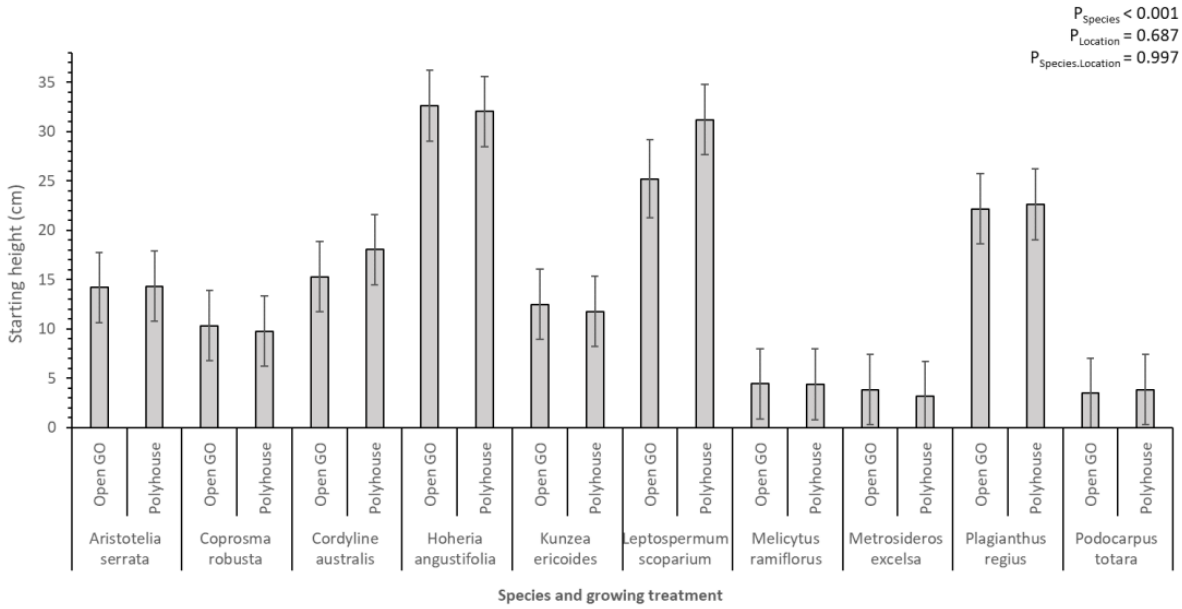

Figure 3.1: Heights of plants at the point of transfer to growing treatments for this trial. Error bars represent the standard errors of the means. GO = grow out.

Final measurement of plant heights at dispatch (July 2020)

Final measurements of seedlings (final heights, height increments relative to measurements at point of transfer, RCD, and mortality) were taken at the point of dispatch from the nursery during July 2020 (Figures 3.2, 3.3, 3.4 and 3.5, respectively). There was a difference in the heights between species and the heights of polyhouse grown plants were significantly taller than open-grown out equivalents (Figure 3.2).

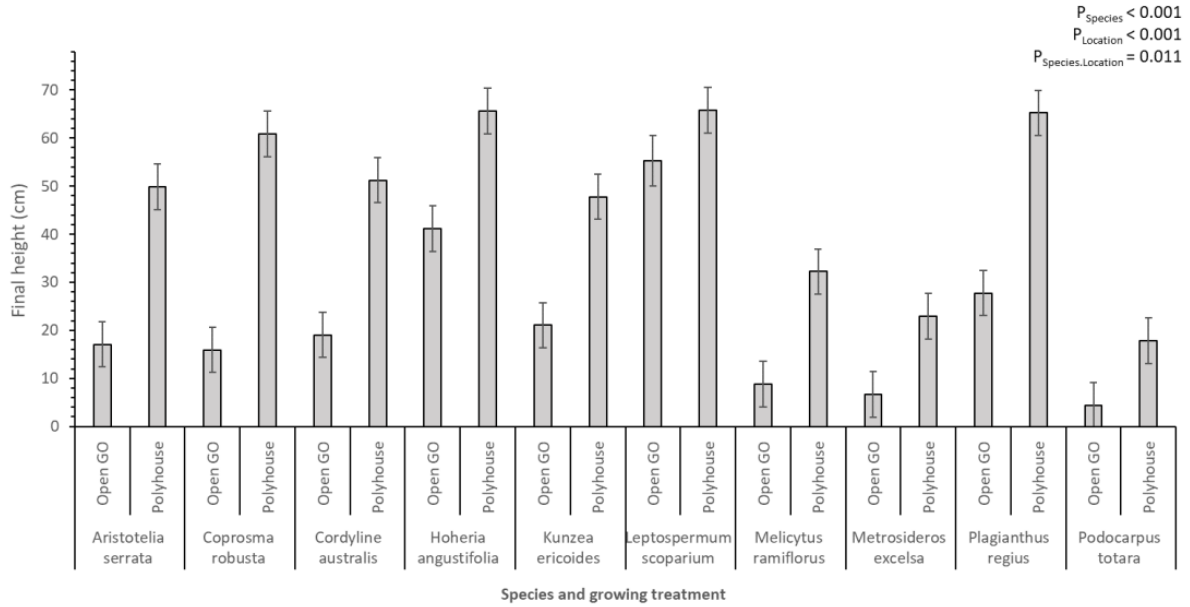

Figure 3.2: Final heights of plants at point of dispatch from the nursery.
Error bars represent the standard errors of the means. GO = grow out.

When comparing the the starting heights and heights at the point of dispatch (Figure 3.3), most plants showed an increase in the height increment with polyhouse conditions compared to open-grown out equivalents at dispatch. However, *Leptospermum scoparium* and *Hoheria angustifolia* did not benefit greatly from polyhouse conditions.

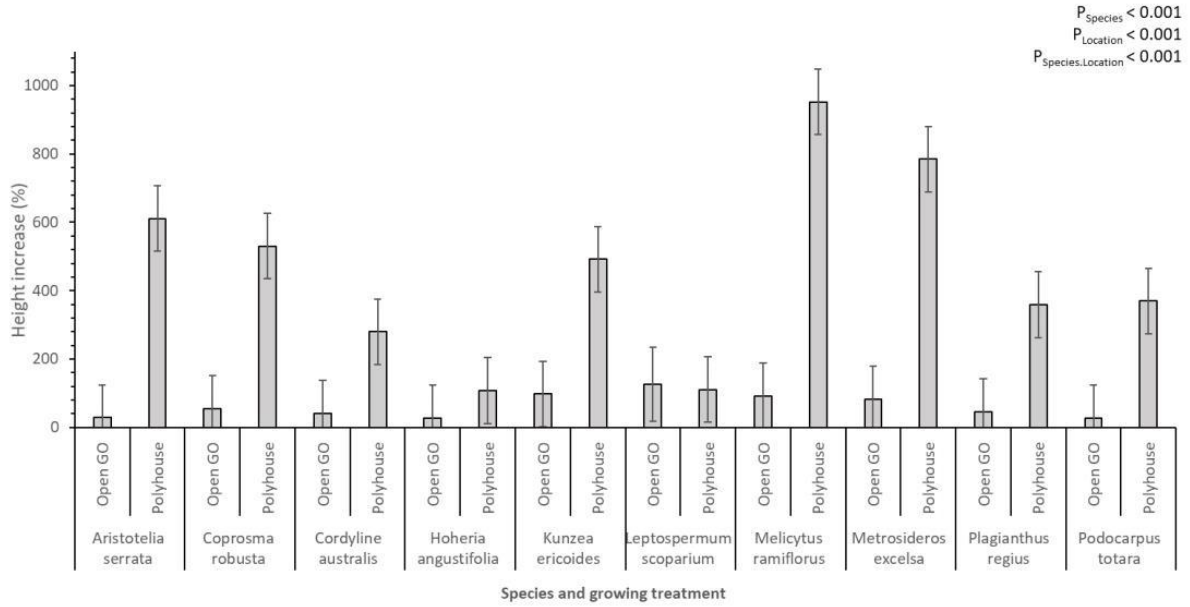

Figure 3.3: Height increase of plants at point of dispatch from the nursery.
Error bars represent the standard errors of the means. GO = grow out.

At the point of dispatch, RCDs were significantly different among species (Figure 3.4). RCD was higher in the polyhouse for the following species: *Aristotelia serrata*, *Kunzea ericoides, Leptospermum scoparium*, *Melicytus excelsa* and *Plagianthus regius*. The remaining species had lower RCDs, revealing a significant species x growing location interaction.

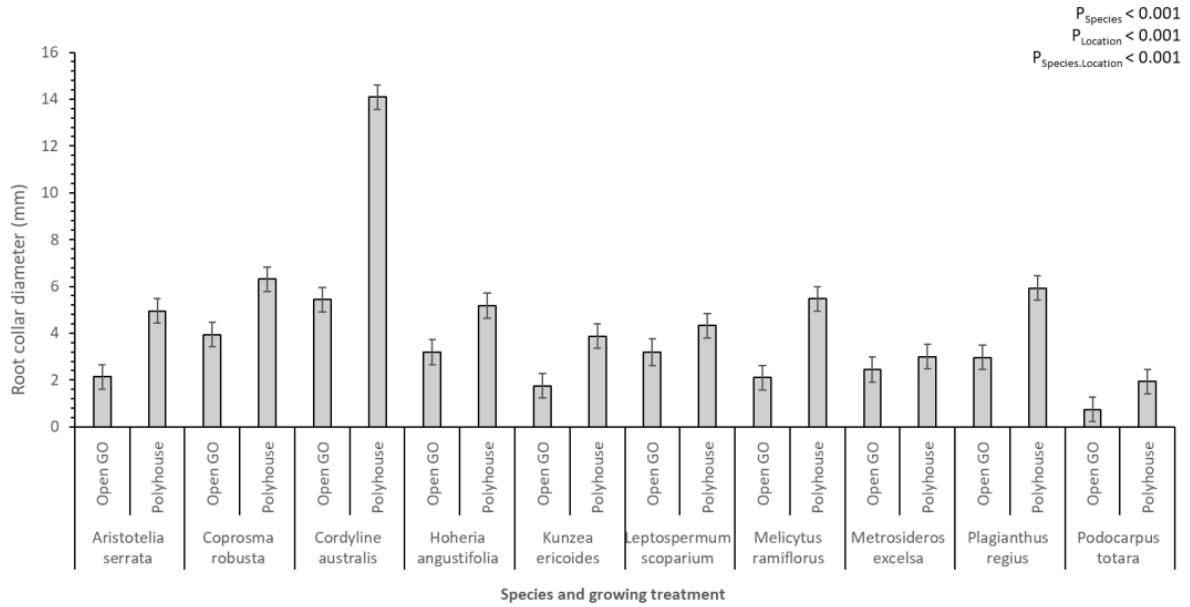

Figure 3.4: Final root collar diameters (RCD) of plants at point of dispatch from the nursery.
Error bars represent the standard errors of the means. GO = grow out.

Plant mortality was significant at the species level, but the response varied among species (Figure 3.5). For *Melicytus excelsa* and *Leptospermum scoparium*, mortality was higher in polyhouse plants, whereas for *Hoheria angustifolia* mortality was higher in the open-grown out plants. The highest mortality was observed in polyhouse grown *Melicytus excelsa*, with high levels also observed in open-grown out plants.

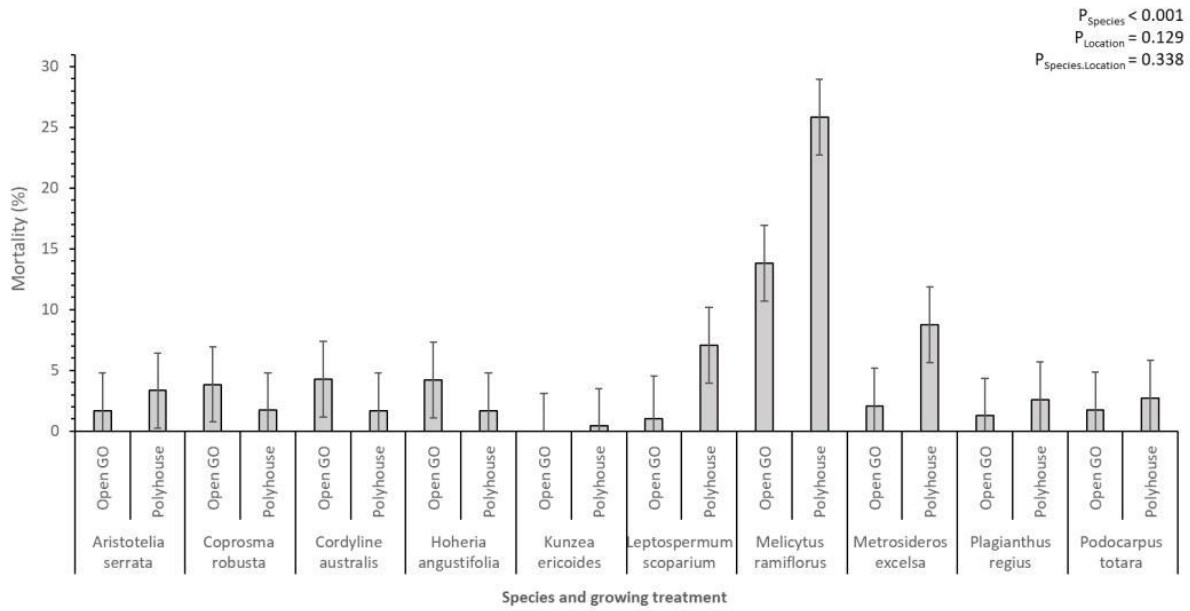

Figure 3.5: Plant mortality under different treatments at the point of dispatch from the nursery, assessed in July 2020.
Error bars represent the standard errors of the means. GO = grow out.

DISCUSSION

In conclusion, all species tested appeared to benefit from growing in a polyhouse, which increased the final height at dispatch compared to open-grown out plants. These results suggest that plants grown with environmental controls had greater survival and a longer seedling production window. However, more research is needed to optimise growing regimes and to increase height and RCD in individual species. Using pots that allow spacing within the polyhouse would be good to test in species where RCD was smaller in the polyhouse grown plants than open-grown out equivalents.

All plants were grown on a standard timeline for comparison purposes, so it may be possible that reducing the time to dispatch may help alleviate the observed reduction in RCD for some rapidly growing species (e.g. *Hoharia angustifolia*).

This project has clearly shown that polyhouses have potential to increase growth rates and may be a useful method for reducing the time taken to grow native plants to dispatch. This could assist in enhancing the growth and survival of native trees in the nursery.

Project 5: Revision of growing media requirements/recommendations for native tree species



BACKGROUND

The growing conditions for plants can improve plant growth and quality. Although it is a common perception that native species prefer media mixes with less fertiliser, media requirements for native tree species need to be tested to optimise growth and survival in the nursery. This project aimed to test a variety of media and fertiliser combinations for growing native tree species to improve growth and make recommendations for optimum media requirements. This will facilitate the production of more native trees without compromising plant health and establishment success.

This project is part of a wider research program spanning 8 key components of propagation. This section relates to Project 5 (Table 1.1) as part of a wider research programme spanning 8 key components of propagation.

Objectives

1. To optimise growth and survival of native trees in the nursery, thereby facilitating the production of more native trees, faster, without compromising plant health and establishment success.
2. To generate recommendations for optimum growing media.

Aims

To test media and fertiliser combinations for growing native tree species.

MATERIALS AND METHODS

Treatments

A total of ten species were used in this project (Table 4.1).

Table 4.1: Species sown for Project 5.

Species name	Common name
Aristotelia serrata	Makomako / Wineberry
Coprosma robusta	Karamu
Cordyline australis	Tī kōuka / Cabbage Tree
Hoheria angustifolia	Narrow-leaved lacebark
Kunzea ericoides	Kānuka
Leptospermum scoparium	Mānuka
Melicytus ramiflorus	Mahoe / Whiteywood
Metrosideros excelsa	Pohutukawa
Plagianthus regius	Manatu / Ribbonwood
Podocarpus totara	Tōtara

Seven different media types were used in this project (Table 4.2).

Table 4.2: Media mixes used in Project 5.

Name	Code
Scion Ellepot - pine mix	Mix A
Scion Ellepot - native mix	Mix B
Minginui tube mix	Mix C
Daltons trial mix	Mix D
Treeline pricking out mix	Mix E
Scion Mānuka cell mix 2019/2020	Mix F
Scion Mānuka cell mix 2018/2019	Mix G

Trial design

A split plot was used, where the main-plot was the species and the sub-plot was the growing media type. Each sub-plot unit is a seedling tray (TS48) with 48 seedlings. A total of 20,160 seedlings were used (10 species x 7 media x 6 replications x 48 seedlings = 20,160). The layout can be found in Appendix 2.

Methodology

1. Sixty trays of each media type were filled with and labelled with their media code. All media combinations were supplied by Daltons.
2. Each of the 10 species were then transplanted into trays, six for each media type.
3. Trays were placed into a polyhouse to assist with establishment success and labelled according to the final trial design.
4. These were then transferred out onto an open table in the nursery in their trial order (Appendix 2).

5. All species x media type combinations were assessed for nursery survival and plant quality during March 2020.
6. Results were communicated at a nursery workshop hosted at Scion on 30 July 2020.

RESULTS

Media characteristics

In this trial, seven media were chosen and represent a good variety of physical components (Figure 4.1), fertiliser combinations (Figure 4.2), and price per cubic metre ($229 - $315).

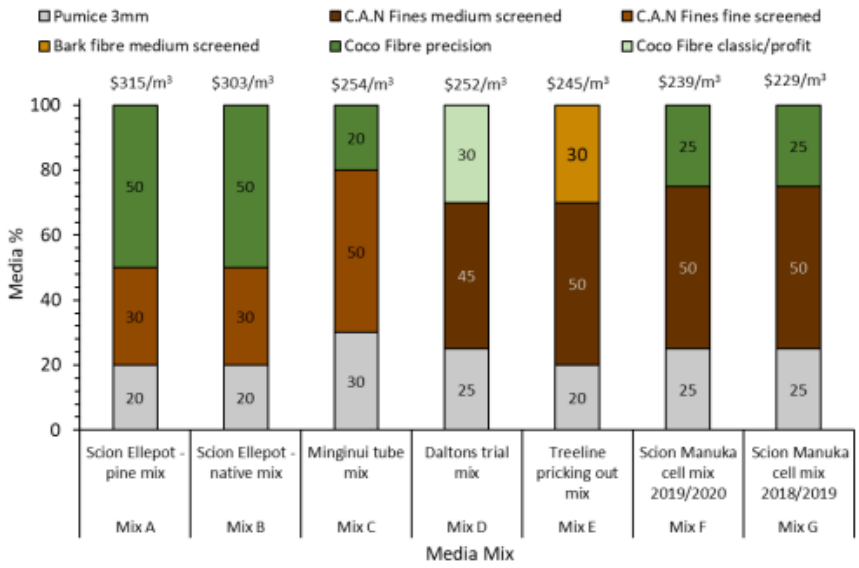

Figure 4.1: Physical components and prices of media mixes used in Project 5.

By the end of November 2019 all species had been pricked-out into the various media treatments (Figure 4.2) and packed out into their trial design on open grow-out tables in the nursery (Appendix 2).

All media had pH within the range of 4.8-5.6, and a range of other physical properties (Table 4.3). The Scion Mānuka mix 2018/2019 (Mix G) had the lowest amount of fertiliser (2.8 kg/m^3) and the lowest cost per 1000 plants ($28.63). The Scion Ellepot pine mix had the highest amount of fertiliser (8.25 kg/m^3) and the highest cost per 1000 plants ($39.38).

Table 4.3: Physical properties of the different media mixes.

	Mix A	Mix B	Mix C	Mix D	Mix E	Mix F	Mix G
Physical properties	Scion Ellepot - pine mix	Scion Ellepot - native mix	Minginui tube mix	Daltons trial mix	Treeline pricking out mix	Scion Mānuka cell mix 2019/2020	Scion Mānuka cell mix 2018/2019
pH	4.8	5.1	5.4	5.6	5.6	5.4	5
Electrical conductivity	1.9	1.8	0.9	1.2	1.2	1.1	1
Air-filled porosity	13	13	15.4	20.9	23	14.3	15.1
Water holding content	56.5	57.6	49.9	49.3	48.6	50.9	52.2
Total controlled-release fertiliser (kg/m^3)	8.25	7.25	2.5	5.75	5.75	4.3	2.8
cost/1000plants	$39.38	$37.88	$31.75	$31.50	$30.63	$29.88	$28.63

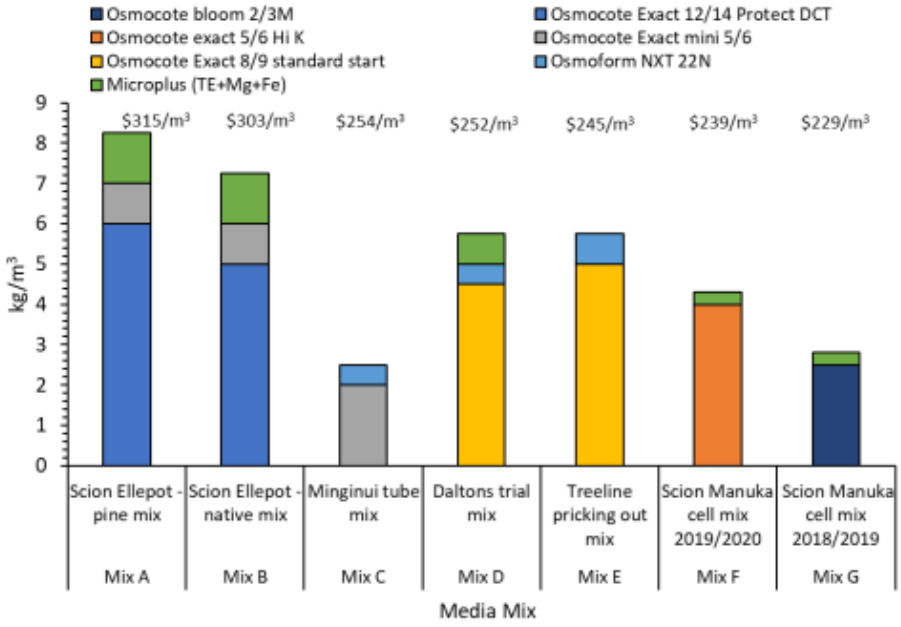

Figure 4.2: Fertiliser components and prices of media mixes used in Project 5.

Plant growth

By December 2019, differences in plant growth were becoming evident (Figures 4.4 and 4.5). Some of the most significant growth differences were observed in *Melicytus ramiflorus* (Figure 4.5).

When looking at final plant heights, there were differences observed across media treatments (Table 4.4). The Scion Mānuka cell mix 2018/2019 (Mix G) consistently produced shorter plants that the other treatments. The tallest plants were observed in the Scion Ellepot - pine mix (Mix A).

The overall survival in this trial was very good, with an average of 98% across all species and media combinations (Table 4.5). The lowest overall survival was observed in the Scion Mānuka cell mix 2018/2019 (Mix G) with 96% survival, although this is unlikely to be statistically different to the other treatments.



Figure 4.3: *Cordyline australis* pricked-out into Dalton's trial mix (Mix D).

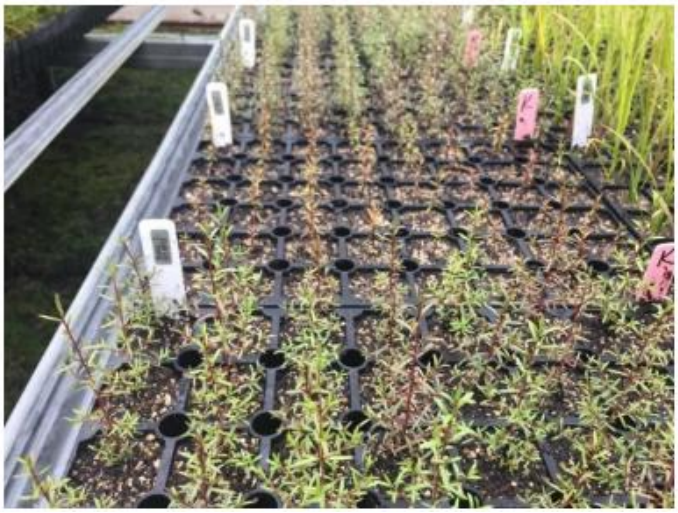

Figure 4.4: Visible growth differences between media types observed in *Kunzea ericoides*.



Figure 4.5: Significant growth differences observed in *Melicytus ramiflorus.*

Table 4.4: Average seedling height (cm), per media treatment.

		Mix A	**Mix B**	**Mix C**	**Mix D**	**Mix E**	**Mix F**	**Mix G**	
Species name	**Common name**	Scion Ellepot - pine mix	Scion Ellepot - native mix	Minginui tube mix	Daltons trial mix	Treeline pricking out mix	Scion Mānuka cell mix 2019/2020	Scion Mānuka cell mix 2018/2019	**Average**
Aristotelia serrata	Makomako / Wineberry	54	45	38	36	30	35	6	**35**
Coprosma robusta	Karamu	21	20	19	15	12	13	10	**16**
Cordyline australis	Tī kōuka / Cabbage Tree	34	33	32	29	28	27	9	**28**
Hoheria angustifolia	Narrow-leaved lacebark	50	45	43	40	40	43	35	**42**
Kunzea ericoides	Kānuka	48	46	39	33	27	29	5	**32**
Leptospermum scoparium	Mānuka	59	62	40	41	38	36	21	**42**
Melicytus ramiflorus	Mahoe / Whiteywood	15	12	11	11	10	9	2	**10**
Metrosideros excelsa	Pohutukawa	12	11	9	8	6	6	2	**8**
Plagianthus regius	Manatu / Ribbonwood	62	58	43	41	45	37	5	**43**
Podocarpus totara	Tōtara	13	10	6	6	6	5	2	**7**
	Average	**37**	**34**	**28**	**26**	**24**	**24**	**10**	**26**

Table 4.5: Final survival of seedlings (%) per media treatment.

		Mix A	**Mix B**	**Mix C**	**Mix D**	**Mix E**	**Mix F**	**Mix G**	
Species name	**Common name**	Scion Ellepot - pine mix	Scion Ellepot - native mix	Minginui tube mix	Daltons trial mix	Treeline pricking out mix	Scion Mānuka cell mix 2019/2020	Scion Mānuka cell mix 2018/2019	**Average**
Aristotelia serrata	Makomako / Wineberry	100	100	100	100	100	100	100	**100**
Coprosma robusta	Karamu	94	94	98	100	100	98	99	**97**
Cordyline australis	Tī kōuka / Cabbage Tree	84	92	97	99	99	98	99	**95**
Hoheria angustifolia	Narrow-leaved lacebark	100	100	100	100	100	100	100	**100**
Kunzea ericoides	Kānuka	100	100	100	100	100	100	100	**100**
Leptospermum scoparium	Mānuka	100	99	100	100	100	99	100	**100**
Melicytus ramiflorus	Mahoe / Whiteywood	100	93	99	99	99	98	78	**95**
Metrosideros excelsa	Pohutukawa	100	100	100	100	100	100	99	**100**
Plagianthus regius	Manatu / Ribbonwood	100	100	100	99	100	100	99	**100**
Podocarpus totara	Tōtara	99	95	94	93	91	91	94	**94**
	Average	**98**	**97**	**99**	**99**	**99**	**98**	**96**	**98**

DISCUSSION

Overall, the best performing media appeared to be Scion Ellepot – pine mix (Mix A), which has the highest fertilizer component. The poorest performing media based on survival and plant heights appears to be Scion Mānuka cell mix 2018/2019 (Mix G) which has the second lowest fertiliser component (Figure 4.2). This media was sourced from a 1-year-old batch already at our nursery and these results suggests that what little control release fertiliser was originally in this mix may have been exhausted before pricking out. Therefore, this media mix should be considered as a zero-fertiliser control equivalent.

These results also indicated that a significant increase in plant height can be achieved by using media that provides the plants with a well-thought-out mix with adequate fertilisation. Nurseries will be able to use this information to improve their own growing media by adjusting the properties given in Table 4.3.

Project 6: Mechanisation to address production bottlenecks



BACKGROUND

The production of many exotic commercial crops involves a highly automated, low-labour system, where trays can be automatically de-stacked, filled with media, dibbled, seed sown, capped, and re-stacked at the other end. This process and allows immense throughput and efficiency, which can help save on production and overcome some of the high price obstacles that currently exist around the cost of individual plants. It also requires minimal human input, which provides more opportunities for technicians to learn new horticulture techniques as opposed to undertaking repetitive menial tasks (such as manual tray filling and pricking out). However, many native forest plant production nurseries are not automated to this extent and the goal of this project was to test the viability of automated propagation technologies for native species production. Importantly, future research will consider the evident trade-off between germination success and handling in automation systems.

This project covers two main container grades: forestry grade (125cc) and large/ retail grade (500cc-1200cc); to demonstrate opportunities for change, irrespective of the species and stock-type of a particular nursery. Of note, the trade-off of automation and employment has not been considered in this approach.

This section of the report relates to Project 6 (Table 1.1) as part of a wider research programme spanning 8 key components of propagation. This section is split into two projects:

1. Mechanised, direct, sowing of native seed
2. Mechanised production of large growing containers.

Objectives

1. To improve nursery efficiency by testing automated seed sowing in the nursery, thereby replacing the need for ‘pricking-out’.
2. To test an alternative, automated, process to replace manual filling of potting bags.

Aims

To trial the suitability of an automated sowing and potting machines for native tree production.

Project 6.1: Mechanised, direct, sowing of native seed

MATERIALS AND METHODS

Treatments

Six species were tested in this project (Table 5.1).

Table 5.1: Species sown for Project 6.1.

Species name	Common name
Aristotelia serrata	Makomako / Wineberry
Coprosma robusta	Karamu
Cordyline australis	Tī kōuka/ Cabbage Tree
Dodonaea viscosa	Ake-ake
Sophora microphylla	Kōwhai (microphylla)

Two methods of propagation were tested:

1. Automated direct sowing
2. Hand sown with pricking-out.

Trial design

A split plot was used, where the main-plot was the propagation method and the sub-plot was the species. A total of 10 replications were used with ANOVA analysis.

Methodology

1. Seed-sowing was optimised prior to the trial.
2. Available seed of each species (Table 5.1) was randomly separated into two sets (Table 5.2).
3. One set of seeds from the species was sown into TS48 trays (using either the Scion Native tree or Mānuka mix) with the automated sowing line. After sowing, trays were placed in a polyhouse for germination.
4. The other set of seed from the species was hand-sown into five germination punnets. After sowing, trays were placed in a polyhouse for germination.
5. Once the hand sown seed started to germinate, germinants were counted and pricked-out into TS48 trays (with the same mix as automated sowing) and placed back into the polyhouse.
6. After approximately four weeks of time in the polyhouse, all seedlings were moved out onto the open grow out tables (or the long-bay polyhouse). Plants were packed into the required trial design.
7. During September, plants were assessed for total germinants, seedling survival and growth, to determine which plants were suitable for early transplanting into larger containers.
8. Separate cost tracking codes were established for tracking costs of direct sowing versus automated sowing.



Figure 5.1: Paul Keech and Patricia Moke-Pouwhare oversee the sowing of *Dodonaea viscosa* using the Scion automated tray filler and sowing line.

Table 5.2: Total seed mass (g) of species and treatments sown in Project 6.1.

Species name	Common name	Mechanised sowing	Manual pricking-out
Aristotelia serrata	Makomako / Wineberry (5g)	5	5
Coprosma robusta	Karamu (10g)	10	10
Cordyline australis	Tī kōuka/ Cabbage Tree (5g)	5	5
Dodonaea viscosa	Ake-ake (5g)	10	10
Sophora microphylla	Kōwhai (microphylla) (5g)	10	10

PROGRESS AND RESULTS

In March 2020, an initial count of seedlings was determined after seeds were pricked-out and trays were in the greenhouse layout. In most cases, the total number of germinants surviving was not hugely different (Table 5.3). Although it was observed that a significantly higher number of trays were used for the mechanical sowing, *Dodonaea viscosa* and *Sophora microphylla* appeared to have performed better if mechanically sown, which is an unexpected but positive result. In all cases, the number of germinants per tray was lower in the mechanical sowing, suggesting that seed requires improved sorting for viability before sowing.

Table 5.3. Germination count of species and treatments in Project 6.1

		Total 48 cell trays sown		**Total germination**		**Germinants per 48 cell tray**	
Species name	**Common name**	Mechanised sowing	Manual pricking out	Mechanised sowing	Manual pricking out	Mechanised sowing	Manual pricking out
Aristotelia serrata	Makomako / Wineberry	34	14	605	594	17.8	42.4
Coprosma robusta	Karamu	32	11	588	528	18.4	48.0
Cordyline australis	Tī kōuka/ Cabbage Tree	25	16	675	768	27.0	48.0
Dodonaea viscosa	Ake-ake	24	1	75	28	3.1	28.0
Sophora microphylla	Kōwhai (microphylla)	38	4	230	158	6.1	39.5

A final count of seedlings produced was carried out in July 2020 (Table 5.4). When looking at the average across all species, mechanised sowing improved the number of seedlings by 18%. However, there was high levels of variation between the species, with a range of -8% to 476%.

Table 5.4. Survival count of species and treatments in Project 6.1

Species name	**Common name**	**Machine**	**Pricking out**	**Total**	**% Survival improvement**
Coprosma robusta	Karamu	609	630	**1239**	-3.3
Cordyline australis	Tī kōuka/ Cabbage Tree	649	528	**1177**	22.9
Aristotelia serrata	Makomako / Wineberry	742	806	**1548**	-7.9
Dodonaea viscosa	Ake-ake	144	25	**169**	476.0
Sophora microphylla	Kōwhai (microphylla)	371	136	**507**	172.8
	Grand total	**2515**	**2125**	**4640**	**18.4**

The final heights of seedlings are shown in Figure 5.2. In most cases, mechanised sowing resulted in larger seedlings. This may be due to the absence of root disturbance, which occurs with seedlings that are pricked-out. The final tray stocking and total number of seedlings produced are shown in Figure 5.3. While pricking out always produced much better stocking in trays, the actual number of seedlings produced was generally higher in the mechanised sowing treatments.

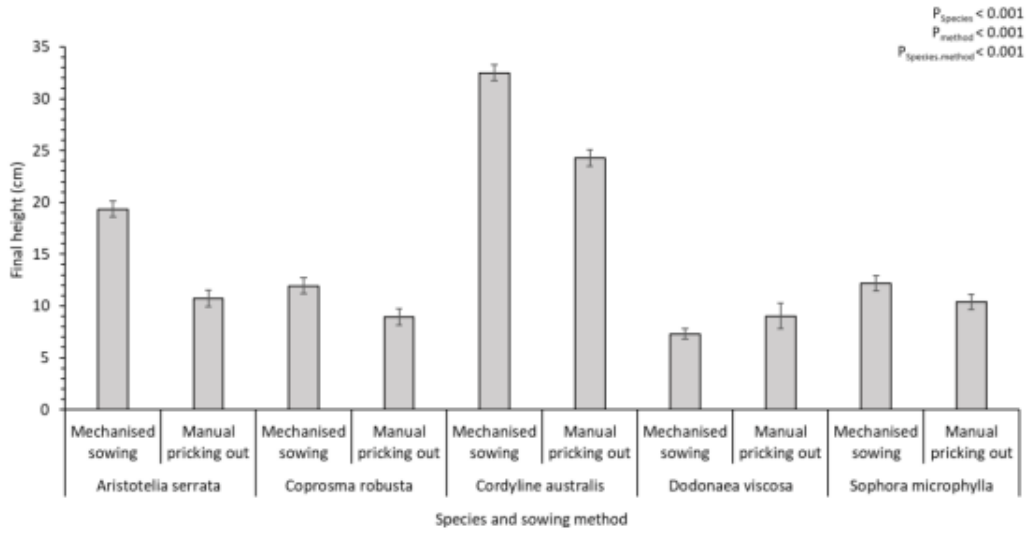

Figure 5.2: Final heights (cm) of treatments in this trial.
Error bars represent the standard errors of the means.

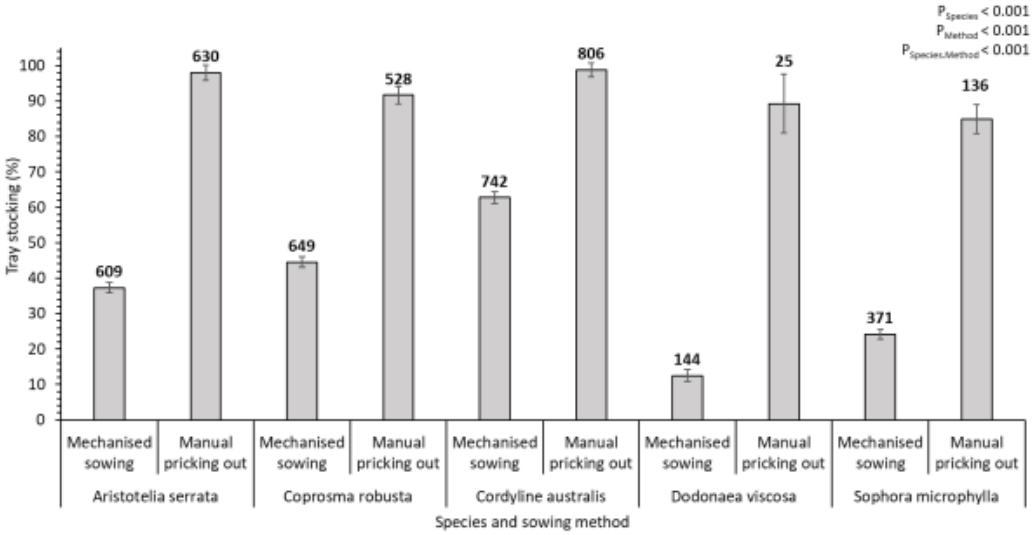

Figure 5.3: Final tray stocking (percentage of cavities with a tree in them) of treatments in this trial.
The numbers above bars represent the number of seedlings produced. Error bars represent the standard errors of the means.

Project 6.2: Mechanised production of large growing containers

MATERIALS AND METHODS

Treatments

A total of thirty-one species were used in this project (Table 5.5).

Table 5.5: Species sowed for Project 6.2.

Species name	Common name
Aristotelia serrata	Makomako / Wineberry
Beilschmiedia tawa	Tawa
Coprosma grandifolia	Kanono
Coprosma robusta	Karamu
Cordyline australis	Tī kōuka / Cabbage Tree
Corynocarpus laevigatus	Karaka
Dodonaea viscosa	Ake-ake
Dacrycarpus dacrydioides	Kahikatea
Hoheria angustifolia	Narrow-leaved lacebark
Kunzea ericoides	Kānuka
Leptospermum scoparium	Mānuka
Lophozonia menziesii	Tawhai / Silver beech
Melicytus ramiflorus	Mahoe / Whiteywood
Metrosideros excelsa	Pohutukawa
Pseudopanax crassifolius	Lancewood
Pseudopanax crassifolius hybrid	Lancewood/ Five finger hybrid
Plagianthus regius	Manatu / Ribbonwood
Podocarpus totara	Tōtara
Sophora tetraptera	Kōwhai
Vitex lucens	Pūriri

Four different container types were used for this project (Table 5.6).

Table 5.6: Container types and sizes used for pricking-out in Project 6.2.

Container type	Container volume
T28 trays	500ml
8.0cm paper pots	700ml
10cm paper pots	900ml
PB2 bags	1200ml

Trial design

Each species and container type combination were replicated 20 times.

Methodology

1. All 20 species were germinated and established.
2. Approximately 1/3 of seedlings were established in one of three container types: 8.0cm paper pots (directly pricked out); 10cm paper pots (potting on); or PB2 bags.
3. A time study for bag preparation and planting was completed.
4. The survival, growth and root form of plants was measured in June/July 2020.
5. The plant quality and suitability of automation was determined in response to these findings.

PROGRESS AND RESULTS

The Ellepot ‘Grow-bag’ machine was successfully installed and commissioned during December 2019. On 13 December, a nursery industry open day was held at Scion to demonstrate the technology and present some early results of the 1BT project (Figures 5.4 and 5.5).

By the end of 22 December, all species had been successfully transplanted into 8cm grow bags, while only 11 species had been successfully transplanted into 10cm paper pots or PB2 bags. The remaining species were potted up during January 2020.



Figure 5.4: Darran Stone (Ellepot) demonstrates the Ellepot “Grow-bag” machine.

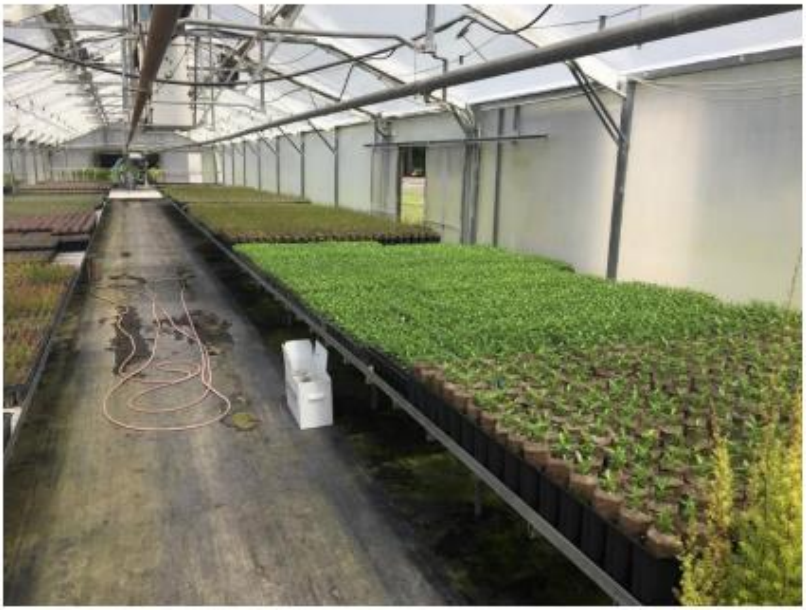

Figure 5.5: Examples of Ellepot “Grow-bags” which have been filled and used for the trial, in the Scion nursery.

Measurements for this trial were undertaken in March 2020. Results showed that there was little difference in the average nursery survival (Table 5.7) across container types for most species. ın July 2020, measurements of final growth at dispatch were taken (Table 5.8) and showed that there was minimal difference in the growth across container types for most species. Notably, *Lophozonia menziesii* performed best when grown in a 125ml container first and then transplanted, whereas *Podocarpus totara* performed best if directly pricked out into an 8cm diameter paper pot.

The use of smaller container types may be appropriate for species that showed no difference in growth across container types, as smaller containers use significantly less media which can reduce nursery plant production costs. The labour costs associated with use of the three different container types were tracked in the Scion nursery (Table 5.9). The results showed that significant labour savings could be made by using both the Ellepot 8cm and 10cm grow bags compared to PB2 bags. However, the use of directly pricking-out into Ellepot grow bags had the most substantial savings, of nearly $90,000. These savings are significant and worth considering for any native plant production system. The smaller containers are also easier to carry and plant in the field and reduce plastic waste by 75-85%.

Table 5.7: Average survival (%) of tree species in each container type.

Species name	Common name	8cm grow bag	10cm grow bag	PB2 bags
Aristotelia serrata	Makomako / Wineberry	100	100	100
Beilschmiedia tawa	Tawa	79	77	99
Coprosma grandifolia	Kanono	100	88	98
Coprosma robusta	Karamu	99	98	98
Cordyline australis	Tī kōuka / Cabbage Tree	97	99	98
Corynocarpus laevigatus	Karaka	97	100	100
Dodonaea viscosa	Ake-ake	94	95	98
Dacrycarpus dacrydioides	Kahikatea	85	100	98
Hoheria angustifolia	Narrow-leaved lacebark	99	100	100
Kunzea ericoides	Kānuka	96	100	100
Leptospermum scoparium	Mānuka	100	100	100
Lophozonia menziesii	Tawhai / Silver beech	77	88	96
Melicytus ramiflorus	Mahoe / Whiteywood	100	99	100
Metrosideros excelsa	Pohutukawa	99	66	64
Pseudopanax crassifolius	Lancewood	100	100	100
Pseudopanax crassifolius hybrid	Lancewood/ Five finger hybrid	100	98	100
Plagianthus regius	Manatu / Ribbonwood	96	100	100
Podocarpus totara	Tōtara	98	100	100
Sophora tetraptera	Kōwhai	100	100	100
Vitex lucens	Pūriri	100	97	97
	Average	**96**	**96**	**97**

Table 5.8: Average height (cm) of tree species in each container type at the point of dispatch from the nursery.

Species name	Common name	8cm grow bag	10cm grow bag	PB2
Aristotelia serrata	Makomako / Wineberry	110.8	101.6	109.3
Beilschmiedia tawa	Tawa			
Cordyline australis	Tī kōuka / Cabbage Tree	61.7	47.6	57.7
Coprosma grandifolia	Kanono	40.0	25.4	26.9
Coprosma robusta	Karamu	84.9	81.1	84.0
Corynocarpus laevigatus	Karaka			
Dacrycarpus dacrydioides	Kahikatea			
Dodonaea viscosa	Ake-ake	105.4	83.4	107.5
Hoheria angustifolia	Narrow-leaved lacebark	109.3	109.0	117.7
Kunzea ericoides	Kānuka	99.5	89.9	98.1
Leptospermum scoparium	Mānuka	102.1	98.9	103.5
Lophozonia menziesii	Tawhai / Silver beech	19.3	18.8	20.2
Melicytus ramiflorus	Māhoe / Whiteywood	61.0	43.6	53.9
Metrosideros excelsa	Pohutukawa	28.8	28.9	26.4
Pseudopanax crassifolius	Lancewood	27.5	29.9	33.7
Pseudopanax crassifolius hybrid	Lancewood/ Five finger hybrid	23.2	22.9	23.5
Plagianthus regius	Manatu / Ribbonwood	97.1	90.3	100.4
Podocarpus totara	Tōtara	33.8	25.4	30.3
Sophora tetraptera	Kōwhai	41.0	43.9	43.7
Vitex lucens	Pūriri	32.0	27.3	36.9
	Average	**84.5**	**71.7**	**79.9**

Table 5.9: Time study results illustrating cost efficiences of producing manually filled bags and mechanised production systems trialled in this project.

Bag type	Filling type	Transplant type	Time per bag (mins)	Time spent bagging 1M plants p.a (hours)	Labour cost for bagging 1M plants p.a (@$20*/hr)	Annual labour saving ($)
PB2 bag	Manual	125ml plug transplant	2.39	39,833	$99,583	
10cm Ellepot grow bag	Machine	125ml plug transplant	1.68	27,917	$69,792	$29,792
8cm Ellepot grow bag	Machine	Direct pricking-out	0.24	4,000	$10,000	$89,583

*The new minimum wage rates, before tax, are: adult – $21.20 an hour (up from $20.00); starting-out – $16.96 per hour (up from $16.00); training – $16.96 per hour (up from $16.00).

PROJECT 6 DISCUSSION

The results from Project 6.1 demonstrate that mechanised sowing has a lot of potential, however specific seed sorting and pre-treatments may be required before mechanised sowing can be successfully implemented in all species.

The results from Project 6.2 show that using Ellepot grow bags improves nursery space utilisation, reduces growing costs and improves transport efficiency. Depending on the goals of individual nurseries, and factors such as labour, the number of plants produced each season and the types of plants grown, pricking-out directly into paper pots could be a really exciting option for reducing labour costs.

The results from this project will be useful for nurseries that are considering using paper pots or exploring infrastructure investment. While they do demonstrate potential for automation, ongoing research is still needed in native plant production. This includes the development of systems that enable the adaptation of production systems, which will be a focus of future work to unlock the power of automation for native plant production.

Project 7: Supplementing native tree seedling supply with cuttings using a mini-hedge system for mother stock



BACKGROUND

The use of mini-hedges for accelerating the production of high-value, genetically improved plants has been proven around the world, including in pine and eucalypt production for timber and pulp. In New Zealand, traditional methods of outside 'stool beds' or 'mother plants' have been utilised for years, although shoot production (thereby harvestable cuttings) is season dependent and does not guarantee a consistent production pipeline. Seed production and supply are highly variable between seasons in many New Zealand native plants, so investigation of technology viability in a native plant production context will be a crucial step towards meeting our 1BT aspirations. Mini-hedges can provide harvestable shoot year-round and produce high value plants (such as taonga species, plants identified as resistant to pests and disease) at a much higher rate than traditional production approaches. This could also widen the window of opportunity to rescue species under threat from incursions.

This section of the report relates to Project 7 (Table 1.1) as part of a wider research programme spanning 8 key components of propagation.

Objectives

1. To test the mini-hedge cutting technique to successfully establish rooted cuttings of native trees.
2. To provide recommendations on species suitable for rooted cutting production.

Aims

To test the suitability of native tree taxa for establishment via mini-hedge cuttings.

MATERIALS AND METHODS

Treatments

Eight species were tested in this project (Table 6.1).

Table 6.1: Species sown for Project 7.

Species name	Common name
Alectryon excelsus	Titoki
Dacrycarpus dacrydioides	Kahikatea
Lophozonia menziesii	Tawhai / Silver beech
Metrosideros excelsa	Pōhutukawa
Podocarpus totara	Tōtara
Sophora microphylla	Kowhai microphylla
Sophora tetraptera	Kowhai tetraptera
Vitex lucens	Puriri

Trial design

This project used randomised complete blocks, with four replications (setting events).

Methodology

1. A total of 350 seedlings of each species were sown and pricked-out into 4cm paperpots.
2. Once well established in the paperpots, seedlings were transplanted into sandbeds in a new nursery facility, at a spacing of 10cm x 15cm.
3. Seeds were established for two weeks prior to removing apical tips.
4. Once sufficient shoot material is available, available shoots were harvested and set into 4cm paper-pots and placed in new facility rooting tunnel on heated beds. This process was repeated monthly for 4 months (which were the replications).
5. Rooting success was assessed at 8-12 weeks after setting, depending on the species.

PROGRESS AND RESULTS

All eight species were pricked out into 10cm Ellepot paperpots, grown out, and transplanted into sand-beds (Figure 6.1). Most species responded well to the environment, and we were able to achieve several rounds of harvesting/setting between March 2020 and April 2021 (Table 6.2). However, *Lophozonia menziesi*, had a low tolerance of the facility's higher temperature through summer, which is to be expected, due to its colder natural range. The other seven species thrived throughout summer and the mini-hedges were incredibly productive.



Figure 6.1: *Lophozonia menziesii*, *Vitex lucens* and *Metrosideros excelsa* potted up as mini-hedges in sandbeds.

Rooting success varied widely (Table 6.2), from 30% success for the *Lophozonia menziesii* to 99% in *Metrosideros excelsa*. We expect that improvements can be made for species which do now root well, through more deliberate climate control, particularly for those with broader leaves and a higher rate of transpiration.

Of note, *Podocarpus totara* produced a high number of harvestable cuttings from the mini-hedges (37 per hedge before setting) with an 80% rooting success. While *Podocarpus totara* has great potential for forestry and long-term revegetation, they are a naturally inconsistent seed source (male and female plants) and are therefore a species of particular interest for propagation from mini-hedges.

In April 2021, final rooting data was collected and the fertigation regime for the mini-hedges was reduced to 5 minutes water a week and 5 minutes fertigation (low concentration of macro-nutrients with slightly higher phosphorus). This kept the plants healthy while allowing easier holding and maintenance, although it decreased the cuttings. If we had wished to resume the trial, or increase cuttings production, a more frequent and higher dose of nitrogen would have boosted shoot growth and therefore increased cuttings.

Table 6.2: Data gathered throughout Project 7.

Species name	Common name	Number of hedges	Cuttings harvested by April 2021	Cuttings set by April 2021*	Average rooting success (%)	Estimated possible cuttings	Estimated yearly cuttings per hedge
Alectryon excelsus	Titoki	158	331	331	40	130	0.8
Dacrycarpus dacrydioides	Kahikatea	121	958	958	49	460	3.8
Lophozonia menziesii	Tawhai / Silver beech	149	822	822	30	245	1.6
Metrosideros excelsa	**Pōhutukawa**	**291**	**5863**	**2359**	**99**	**5850**	**20.1**
Podocarpus totara	**Tōtara**	**637**	**23578**	**3948**	**80**	**18750**	**29.4**
Sophora microphylla	**Kōwhai microphylla**	**83**	**5322**	**3696**	**68**	**3600**	**43.4**
Sophora tetraptera	**Kōwhai tetraptera**	**82**	**5268**	**1942**	**62**	**3250**	**39.6**
Vitex lucens	Puriri	208	834	834	66	550	2.6
	Total	**1729**	**42976**	**14068**	**67**	**32590**	

Species in bold show great potential for use in the mini-hedge system.

DISCUSSION

These results suggest that mini-hedges are a good production model for cuttings from both *Podocarpus totara* and *Metrosideros excelsa* and is high enough to be deployed at scale. This could also be considered for large-scale production of the two kōwhai species, which also had reasonably high cutting productions. However, more research is needed to explore this further.

The mini-cutting system could be considered by nurseries for cuttings production once factors such as financial analysis and infrastructure required have been considered. This system has high potential, as seed production is not always reliable in our native tree species. Furthermore, depending on the goals of the plant production and planting, the genetic diversity of the planted forest can be managed by the genetic diversity of the stool-beds/mother-plants.

Project 8: Plant quality system



BACKGROUND

The Scion plant quality workshop was held to communicate our findings with industry and co-develop a plant quality system. All attendees were invited to contribute, as it was crucial that we received input from experts across a vast range of fields. The findings from this workshop are outlined in this report.

This section of the report relates to Project 8 (Table 1.1) as part of a wider research programme spanning 8 key components of propagation.

Objectives

1. To discuss plant quality parameters with key native tree establishment stakeholders in a workshop.
2. To document and refine plant quality parameter expectations according to species and container type following workshop discussions and recommendations.

Aim

Provision of data that can be used to initiate an industry standard for plant quality.

METHODS

1. Completed the analysis of plant quality parameter ranges (age, height, RCD) of plants measured as part of this 1BT trial series.
2. Invited stakeholders including nursery owners, managers and staff, as well as companies, councils, and trusts that establish native trees, to attend a workshop on plant quality at Scion in October 2020.
3. Provide a project overview and information that is sufficient for discussion and engagement for refining quality recommendations.
4. Provide a summary report of the workshop to all participants, which includes participant recommendations of plant quality parameters.

PROGRESS AND RESULTS

The plant quality workshop was hosted by Scion, on the Te Papa Tipu innovation park campus, Rotorua. It was designed for engagement with local, regional and national stakeholders in the 1BT project. The invited stakeholders each have a different role to play in meeting New Zealand's afforestation goals, ranging from large-scale containerised forestry nurseries, to small scale ecological restoration companies. The aim of the workshop was to demonstrate the early results of the 1BT container type trial and collaborate with different groups on setting new standards for effective and sustainable plant establishment.

The groups who attended included:

- Advanced Hort Ltd
- ArborGen
- Bay of Plenty Regional Council
- Comvita
- Daltons Ltd
- EcoResto
- Ellepot A/S
- Forest360
- Forevergreen Seedlings Ltd
- Kakaho Bay Limited
- Landcare Okareka
- Landcorp Farming Ltd
- Matariki Forests
- Minginui Nursery
- Ministry of Primary Industries
- PF Olsen nursery
- Pinehurst Associates Limited
- Project Parore
- Pukekauri Farms
- Rotorua Forest Nursery
- Summit Forests
- Te Arawa Lakes Trust
- Te Uru Rākau
- Timberlands Ltd
- Tipu Wai
- Treeline Native Nursery
- Waka Kotahi.

Following the presentations (Figure 7.1), the group was taken on a tour around Scion's Nursery, where Darran from Ellepot demonstrated the Ellebag (8cm) and Ellepot (4cm) machines. These have been used successfully in Scion's trials native cuttings trials (see Project 7). Darran explained the high impact that automation has for nursery managers and forest growers and highlighted the efficiency with which this healthy and sustainable plant-stock can be grown for field establishment.

After the tour, workshop participants met back at the conference room, where they self-selected into small groups of 5-6 members from different organisations (Figure 7.1).

The preliminary results of the container type trial (Project 3) were presented at this workshop. This project compared the survival and growth of New Zealand native trees and shrubs across various container types and volumes. The plant quality workshop encouraged a dialogue between

stakeholders, to discuss the data presented in relation to their anecdotal experience growing or planting native trees. Groups worked together to provide general guidelines for acceptable container volumes, sizes and plant ages (from a logistical perspective), based on data on the establishment, growth and survival of some of our most popular re-vegetation species around Rotorua.

The results and recommendations from this workshop are presented in Table 7.1.

Table 7.1: Summary of best practise guidelines based on results of the plant quality workshop.

Species name	Common name	Volume rec. (cc.)	Plug type	Age rec. (months)	Height rec. (mm)	RCD rec. (mm)	Topping
Aristotelia serrata	Makomako / Wineberry	700	Elle 8cm (Paper)	7-11	80-110	8-15mm	Yes
Coprosma grandifolia	Kanono	700	Elle 8cm (Paper)	10-16	30-50	5-8mm	No
Coprosma robusta	Karamu	90	Std plus TS45	8-10	45-55	3-7mm	Yes
Cordyline australis	Tī kōuka / Cabbage Tree	90	Std plus TS45	6-9	25-40	5-8mm	Never
Dodonaea viscosa	Ake-ake	90	Elle 3.5 (Paper)	4	35-45	4-5mm	Never
Kunzea ericoides	Kānuka	700	Elle 8cm (Paper)	8-12	60-105	5-7mm	Sometimes
Leptospermum scoparium	Mānuka	90	Elle 3.5 (Paper)	6-9	40-60	4-6mm	Always
Melicytus ramiflorus	Mahoe / Whiteywood	90	Elle 3.5 (Paper)	6-9	30-50	5-9mm	Sometimes
Podocarpus totara	Tōtara	125	Elle 4cm (Paper)	11-13	30+	2-4mm	Never
Plagianthus regius	Manatu / Ribbonwood	700	Elle 8cm (Paper)	10-13	75-85	8-10mm	Sometimes



Craig Ford: Acceleration of Native tree propagation, 1BT Covid response Objective 2 feedback – Managing nursery stocks, early field trial measurements



Carol Rolando: 1BT Towards Tree Establishment Success! Vegetation management (VM) For Indigenous Tree Establishment Progress.



Karen Bayne: 1BT Covid response Objective 1 feedback – Industry Survey on options to extend the planting season



Alexander Lloyd: 1BT Covid response Objective 2 feedback – Holding plant stock during disruptions to the planting season.





Figure 7.1: Plant quality workshop.

CONCLUSION

These recommendations will provide insight into what consistent plant quality specifications might look like for native tree production and may be useful for nurseries in the context of their own plant production.

Appendix

APPENDIX 1 – PROJECT 2

Comprehensive results of container type trial by species

***Dodonaea viscosa* (Ake Ake)**

Final container type	First container type	Average survival %	Average of average height
3.5cm paper pots - 90ml	3.5cm paper pots - 90ml	96.7	37.0
Hiko V90 - 90ml	Hiko V90 - 90ml	100.0	65.0
TS45 - 90ml	TS45 - 90ml	100.0	56.1
4.0cm paper pots - 125ml	4.0cm paper pots - 125ml	91.0	54.0
TS48 - 125ml	TS48 - 125ml	96.6	53.1
Hiko v150	Hiko v150	100.0	38.3
Hiko v310	Hiko v310	95.2	82.6
T28	T28	98.2	108.1
8cm grow bag	8cm grow bag	94.0	96.5
10cm grow bag	3.5cm paper pots - 90ml	93.8	85.8
	4.0cm Paper pots - 125ml	90.6	86.3
	Hiko v150	96.9	83.9
	TS48 - 125ml	100.0	75.2
PB2	3.5cm paper pots - 90ml	100.0	85.8
	4.0cm paper pots - 125ml	100.0	102.3
	Hiko v150	93.8	102.3
	TS48 - 125ml	100.0	100.3

***Cordyline australis* (Ti- Kōuka/Cabbage Tree)**

Final container type	First container type	Average survival %	Average of average height
3.5cm paper pots - 90ml	3.5cm paper pots - 90ml	92.2	39.8
Hiko V90 - 90ml	Hiko V90 - 90ml	88.1	36.8
TS45 - 90ml	TS45 - 90ml	77.4	31.5
4.0cm paper pots - 125ml	4.0cm paper pots - 125ml	100.0	37.9
TS48 - 125ml	TS48 - 125ml	91.3	36.2
Hiko v150	Hiko v150	98.0	37.0
Hiko v310	Hiko v310	97.8	44.2
T28	T28	82.1	56.6
8cm grow bag	8cm grow bag	97.1	64.7
10cm grow bag	3.5cm paper pots - 90ml	99.3	49.1
	4.0cm paper pots - 125ml	97.9	54.0
	Hiko v150	100.0	47.8
	TS48 - 125ml	99.3	50.0
PB2	3.5cm paper pots - 90ml	97.5	61.6
	4.0cm Paper pots - 125ml	99.3	59.5
	Hiko v150	98.6	55.8
	TS48 - 125ml	98.6	52.2

***Pseudopanax arboreus* (Five Finger)**

Final container type	First container type	Average survival %	Average of average height
3.5cm paper pots - 90ml	3.5cm paper pots - 90ml	100.0	6.4
4.0cm paper pots - 125ml	4.0cm paper pots - 125ml	100.0	7.9
TS48 - 125ml	TS48 - 125ml	100.0	6.7
Hiko v150	Hiko v150	100.0	14.3
Hiko v310	Hiko v310	100.0	20.8
T28	T28	100.0	28.0
8cm grow bag	8cm grow bag	100.0	20.9
10cm grow bag	3.5cm paper pots - 90ml	100.0	15.3
	4.0cm Paper pots - 125ml	100.0	23.6
	Hiko v150	92.3	15.3
	TS48 - 125ml	100.0	28.3
PB2	3.5cm paper pots - 90ml	100.0	15.1
	4.0cm paper pots - 125ml	100.0	28.3
	Hiko v150	100.0	20.4
	TS48 - 125ml	100.0	18.0

***Hoheria angustifolia (*Narrow-leaved lacebark)**

Final container type	First container type	Average survival %	Average of average height
3.5cm paper pots - 90ml	3.5cm paper pots - 90ml	97.4	70.5
TS45 - 90ml	TS45 - 90ml	100.0	70.2
4.0cm paper pots - 125ml	4.0cm paper pots - 125ml	93.5	75.5
TS48 - 125ml	TS48 - 125ml	90.9	72.6
Hiko v150	Hiko v150	100.0	68.9
Hiko v310	Hiko v310	100.0	77.6
T28	T28	100.0	108.4
8cm grow bag	8cm grow bag	98.6	108.5
10cm grow bag	3.5cm paper pots - 90ml	100.0	105.0
	4.0cm Paper pots - 125ml	100.0	111.8
	Hiko v150	98.4	95.8
	TS48 - 125ml	100.0	102.2
PB2	3.5cm paper pots - 90ml	99.5	117.7
	4.0cm paper pots - 125ml	100.0	106.7
	Hiko v150	100.0	115.7
	TS48 - 125ml	99.5	112.9

***Dacrycarpus dacrydioides* (Kahikatea)**

Final container type	First container type	Average survival %	Average of average height
3.5cm paper pots - 90ml	3.5cm paper pots - 90ml	97.1	9.3
Hiko V90 - 90ml	Hiko V90 - 90ml	100.0	13.1
4.0cm paper pots - 125ml	4.0cm paper pots - 125ml	90.9	10.9
Hiko v310	Hiko v310	100.0	20.1
T28	T28	100.0	12.4
8cm grow bag	8cm grow bag	85.0	12.5
10cm grow bag	3.5cm paper pots - 90ml	100.0	9.2
	4.0cm Paper pots - 125ml	100.0	13.4
	Hiko v150	100.0	12.9
	TS48 - 125ml	100.0	12.3
PB2	3.5cm paper pots - 90ml	93.8	9.2
	4.0cm paper pots - 125ml	100.0	13.0
	Hiko v150	100.0	14.8
	TS48 - 125ml	100.0	12.8

***Coprosma grandifolia* (Kanono)**

Final container type	First container type	Average survival %	Average of average height
3.5cm paper pots - 90ml	3.5cm paper pots - 90ml	100.0	15.5
Hiko V90 - 90ml	Hiko V90 - 90ml	97.6	20.7
TS45 - 90ml	TS45 - 90ml	84.9	13.2
4.0cm paper pots - 125ml	4.0cm paper pots - 125ml	100.0	17.2
TS48 - 125ml	TS48 - 125ml	100.0	17.0
Hiko v150	Hiko v150	92.3	18.4
Hiko v310	Hiko v310	100.0	35.1
T28	T28	50.0	32.8
8cm grow bag	8cm grow bag	100.0	31.5
10cm grow bag	3.5cm paper pots - 90ml	100.0	18.4
	4.0cm paper pots - 125ml	87.5	16.8
	Hiko v150	81.3	16.3
	TS48 - 125ml	81.3	19.3
PB2	3.5cm paper pots - 90ml	100.0	20.1
	4.0cm paper pots - 125ml	100.0	24.3
	Hiko v150	93.8	18.3
	TS48 - 125ml	100.0	21.3

***Kunzea ericoides* (Kānuka)**

Final container type	First container type	Average survival %	Average of average height
3.5cm paper pots - 90ml	3.5cm paper pots - 90ml	100.0	69.2
Hiko V90 - 90ml	Hiko V90 - 90ml	98.0	50.4
TS45 - 90ml	TS45 - 90ml	96.4	67.3
4.0cm paper pots - 125ml	4.0cm paper pots - 125ml	100.0	66.6
TS48 - 125ml	TS48 - 125ml	100.0	70.3
Hiko v150	Hiko v150	100.0	81.8
Hiko v310	Hiko v310	100.0	100.3
T28	T28	100.0	97.3
8cm grow bag	8cm grow bag	96.5	102.7
10cm grow bag	3.5cm paper pots - 90ml	99.7	83.7
	4.0cm paper pots - 125ml	99.7	84.2
	Hiko v150	100.0	98.1
	TS48 - 125ml	100.0	86.3
PB2	3.5cm paper pots - 90ml	99.7	91.9
	4.0cm paper pots - 125ml	99.7	98.2
	Hiko v150	100.0	95.3
	TS48 - 125ml	100.0	87.1

***Corynocarpus laevigatus* (Karaka)**

Final container type	First container type	Average survival %	Average of average height
8cm grow bag	8cm grow bag	96.8	21.3
10cm grow bag	10cm grow bag	100.0	38.1
PB2	PB2	100.0	23.1

***Coprosma robusta* (Karamu)**

Final container type	First container type	Average survival %	Average of average height
3.5cm paper pots - 90ml	3.5cm paper pots - 90ml	99.0	47.0
Hiko V90 - 90ml	Hiko V90 - 90ml	100.0	62.4
TS45 - 90ml	TS45 - 90ml	100.0	67.3
4.0cm paper pots - 125ml	4.0cm paper pots - 125ml	100.0	51.1
TS48 - 125ml	TS48 - 125ml	98.3	57.0
Hiko v150	Hiko v150	100.0	42.2
Hiko v310	Hiko v310	100.0	63.1
T28	T28	100.0	97.3
8cm grow bag	8cm grow bag	99.1	84.3
10cm grow bag	3.5cm paper pots - 90ml	98.1	80.6
	4.0cm paper pots - 125ml	98.8	85.8
	Hiko v150	97.7	81.3
	TS48 - 125ml	97.1	79.8
PB2	3.5cm paper pots - 90ml	98.7	87.0
	4.0cm paper pots - 125ml	99.1	84.8
	Hiko v150	96.5	88.8
	TS48 - 125ml	96.9	85.0

***Sophora microphylla* (Kowhai microphylla)**

Final container type	First container type	Average survival %	Average of average height
3.5cm paper pots - 90ml	3.5cm paper pots - 90ml	100.0	31.5
TS45 - 90ml	TS45 - 90ml	100.0	35.3
4.0cm paper pots - 125ml	4.0cm paper pots - 125ml	100.0	33.0
TS48 - 125ml	TS48 - 125ml	100.0	32.2
Hiko v150	Hiko v150	100.0	33.4
Hiko v310	Hiko v310	100.0	43.2
T28	T28	100.0	38.8
8cm grow bag	8cm grow bag	100.0	33.3
10cm grow bag	3.5cm paper pots - 90ml	100.0	31.2
	4.0cm paper pots - 125ml	100.0	31.9
	Hiko v150	100.0	29.3
	TS48 - 125ml	100.0	23.9
PB2	3.5cm paper pots - 90ml	100.0	27.3
	4.0cm paper pots - 125ml	100.0	27.8
	Hiko v150	100.0	22.4
	TS48 - 125ml	100.0	27.4

***Sophora tetraptera* (Kowhai tetraptera)**

Final container type	First container type	Average survival %	Average of average height
8cm grow bag	8cm grow bag	94.5	21.9

***Pseudopanax crassifolius* (Lancewood)**

Final container type	First container type	Average survival %	Average of average height
3.5cm paper pots - 90ml	3.5cm paper pots - 90ml	100.0	6.5
4.0cm paper pots - 125ml	4.0cm paper pots - 125ml	100.0	16.8
TS48 - 125ml	TS48 - 125ml	100.0	10.6
Hiko v150	Hiko v150	100.0	13.3
Hiko v310	Hiko v310	100.0	31.8
T28	T28	100.0	33.6
8cm grow bag	8cm grow bag	100.0	28.6
10cm grow bag	3.5cm paper pots - 90ml	100.0	19.6
	4.0cm paper pots - 125ml	100.0	28.9
	Hiko v150	100.0	23.5
	TS48 - 125ml	100.0	18.3
PB2	3.5cm paper pots - 90ml	100.0	16.2
	4.0cm paper pots - 125ml	100.0	26.0
	Hiko v150	100.0	29.6
	TS48 - 125ml	100.0	17.9

***Melicytus ramiflorus* (Mahoe)**

Final container type	First container type	Average survival %	Average of average height
3.5cm paper pots - 90ml	3.5cm paper pots - 90ml	96.5	27.4
Hiko V90 - 90ml	Hiko V90 - 90ml	96.0	26.4
TS45 - 90ml	TS45 - 90ml	96.6	31.6
4.0cm paper pots - 125ml	4.0cm paper pots - 125ml	99.0	29.9
TS48 - 125ml	TS48 - 125ml	100.0	27.7
Hiko v150	Hiko v150	100.0	23.8
Hiko v310	Hiko v310	100.0	40.3
T28	T28	100.0	61.3
8cm grow bag	8cm grow bag	100.0	51.5
10cm grow bag	3.5cm paper pots - 90ml	99.3	37.1
	4.0cm paper pots - 125ml	100.0	36.3
	Hiko v150	100.0	40.2
	TS48 - 125ml	98.6	31.3
PB2	3.5cm paper pots - 90ml	100.0	40.7
	4.0cm paper pots - 125ml	100.0	41.4
	Hiko v150	100.0	50.5
	TS48 - 125ml	99.3	44.8

***Leptospermum scoparium* (Mānuka)**

Final container type	First container type	Average survival %	Average of average height
3.5cm paper pots - 90ml	3.5cm paper pots - 90ml	97.3	79.6
Hiko V90 - 90ml	Hiko V90 - 90ml	87.5	94.0
TS45 - 90ml	TS45 - 90ml	98.1	80.3
4.0cm paper pots - 125ml	4.0cm paper pots - 125ml	98.0	82.6
TS48 - 125ml	TS48 - 125ml	95.3	86.2
Hiko v150	Hiko v150	100.0	85.8
Hiko v310	Hiko v310	99.0	99.6
T28	T28	100.0	97.5
8cm grow bag	8cm grow bag	99.6	89.2
10cm grow bag	3.5cm paper pots - 90ml	99.8	106.4
	4.0cm paper pots - 125ml	100.0	102.9
	Hiko v150	100.0	96.4
	TS48 - 125ml	100.0	106.0
PB2	3.5cm paper pots - 90ml	99.7	102.0
	4.0cm paper pots - 125ml	100.0	95.5
	Hiko v150	100.0	104.2
	TS48 - 125ml	100.0	91.9

***Metrosideros excelsa* (Pohutukawa)**

Final container type	First container type	Average survival %	Average of average height
3.5cm paper pots - 90ml	3.5cm paper pots - 90ml	100.0	19.8
Hiko V90 - 90ml	Hiko V90 - 90ml	66.3	10.8
TS45 - 90ml	TS45 - 90ml	84.4	16.3
4.0cm paper pots - 125ml	4.0cm paper pots - 125ml	96.0	12.8
TS48 - 125ml	TS48 - 125ml	73.4	10.9
Hiko v150	Hiko v150	61.9	14.8
Hiko v310	Hiko v310	81.7	27.7
8cm grow bag	8cm grow bag	99.3	18.8
10cm grow bag	3.5cm paper pots - 90ml	93.8	13.7
	4.0cm paper pots - 125ml	33.3	14.5
	Hiko v150	68.8	14.8
	TS48 - 125ml	66.7	16.3
PB2	3.5cm paper pots - 90ml	77.1	13.7
	4.0cm paper pots - 125ml	41.7	13.3
	Hiko v150	83.3	16.7
	TS48 - 125ml	52.1	14.9

***Vitex lucens* (Pūriri)**

Final container type	First container type	Average survival %	Average of average height
TS45 - 90ml	TS45 - 90ml	97.1	19.4
4.0cm paper pots - 125ml	4.0cm paper pots - 125ml	85.7	13.8
Hiko v150	Hiko v150	83.3	14.6
Hiko v310	Hiko v310	93.8	19.8
T28	T28	100.0	41.6
8cm grow bag	8cm grow bag	100.0	34.7
10cm grow bag	3.5cm paper pots - 90ml	100.0	32.3
	4.0cm paper pots - 125ml	100.0	35.3
	Hiko v150	93.8	23.3
	TS48 - 125ml	93.8	21.4
PB2	3.5cm paper pots - 90ml	100.0	41.2
	4.0cm paper pots - 125ml	100.0	35.2
	Hiko v150	93.8	26.8
	TS48 - 125ml	93.8	26.2

***Plagianthus regius* (Ribbonwood)**

Final container type	First container type	Average survival %	Average of average height
3.5cm paper pots - 90ml	3.5cm paper pots - 90ml	100.0	65.3
Hiko V90 - 90ml	Hiko V90 - 90ml	100.0	67.3
TS45 - 90ml	TS45 - 90ml	100.0	75.2
4.0cm paper pots - 125ml	4.0cm paper pots - 125ml	100.0	67.2
TS48 - 125ml	TS48 - 125ml	100.0	77.3
Hiko v150	Hiko v150	100.0	71.4
Hiko v310	Hiko v310	100.0	93.4
T28	T28	100.0	101.6
8cm grow bag	8cm grow bag	96.0	94.3
10cm grow bag	3.5cm paper pots - 90ml	100.0	96.3
	4.0cm paper pots - 125ml	100.0	95.3
	Hiko v150	100.0	101.3
	TS48 - 125ml	100.0	100.8
PB2	3.5cm paper pots - 90ml	100.0	101.7
	4.0cm paper pots - 125ml	100.0	101.2
	Hiko v150	100.0	101.3
	TS48 - 125ml	100.0	113.8

***Beilschmiedia tawa* (Tawa)**

Final container type	First container type	Average survival %	Average of average height
8cm grow bag	8cm grow bag	78.9	14.4
10cm grow bag	10cm grow bag	77.4	13.4
PB2	PB2	99.4	14.0

***Lophozonia menziesii* (Tawhai)**

Final container type	First container type	Average survival %	Average of average height
4.0cm paper pots - 125ml	4.0cm paper pots - 125ml	45.5	20.9
T28	T28	85.7	25.5
8cm grow bag	8cm grow bag	76.7	15.4
10cm grow bag	3.5cm paper pots - 90ml	100.0	12.8
	4.0cm paper pots - 125ml	100.0	16.2
	Hiko v150	100.0	17.7
	TS48 - 125ml	50.0	13.0
PB2	3.5cm paper pots - 90ml	93.8	15.6
	4.0cm paper pots - 125ml	91.7	17.5
	Hiko v150	100.0	15.6
	TS48 - 125ml	100.0	17.5

***Podocarpus totara* (Tōtara)**

Final container type	First container type	Average survival %	Average of average height
3.5cm paper pots - 90ml	3.5cm paper pots - 90ml	98.8	18.5
Hiko V90 - 90ml	Hiko V90 - 90ml	100.0	20.9
TS45 - 90ml	TS45 - 90ml	92.8	21.9
4.0cm paper pots - 125ml	4.0cm paper pots - 125ml	97.5	21.9
TS48 - 125ml	TS48 - 125ml	96.3	24.1
Hiko v150	Hiko v150	100.0	16.8
Hiko v310	Hiko v310	97.2	27.4
T28	T28	99.5	31.3
8cm grow bag	8cm grow bag	98.2	33.3
10cm grow bag	3.5cm paper pots - 90ml	100.0	21.0
	4.0cm paper pots - 125ml	100.0	21.3
	Hiko v150	100.0	21.3
	TS48 - 125ml	100.0	16.3
PB2	3.5cm paper pots - 90ml	100.0	20.9
	4.0cm paper pots - 125ml	100.0	25.5
	Hiko v150	100.0	26.3
	TS48 - 125ml	100.0	17.3

***Aristotelia serrata* (Wineberry)**

Final container type	First container type	Average survival %	Average of average height
3.5cm paper pots - 90ml	3.5cm paper pots - 90ml	100.0	64.3
Hiko V90 - 90ml	Hiko V90 - 90ml	98.7	67.3
TS45 - 90ml	TS45 - 90ml	100.0	68.8
4.0cm paper pots - 125ml	4.0cm paper pots - 125ml	97.1	76.4
TS48 - 125ml	TS48 - 125ml	100.0	68.7
Hiko v150	Hiko v150	98.0	74.9
Hiko v310	Hiko v310	100.0	112.4
T28	T28	96.4	130.3
8cm grow bag	8cm grow bag	100.0	126.2
10cm grow bag	3.5cm paper pots - 90ml	100.0	106.8
	4.0cm paper pots - 125ml	100.0	107.8
	Hiko v150	100.0	112.5
	TS48 - 125ml	100.0	110.8
PB2	3.5cm paper pots - 90ml	100.0	112.8
	4.0cm paper pots - 125ml	100.0	123.9
	Hiko v150	100.0	108.8
	TS48 - 125ml	100.0	105.3

Grand total across all species	Average survival %	Average of average height
	96.1	**50.3**

APPENDIX 2 – PROJECT 5

Trial layout for Project 5: Media type trial

Rep 1					Rep 2					Rep 3				
M1 Pohut Mix A	M28 Wineb Mix F	M29 Karam Mix F	M56 Manuk Mix C	M57 Mahoe Mix A	M84 Manuk Mix E	M85 Karam Mix B	M112 Ribbo Mix A	M113 Ti Ko Mix G	M140 Mahoe Mix B	M141 Karam Mix C	M168 Pohut Mix B	M169 Manuk Mix C	M196 Wineb Mix F	M197 Totar Mix G
M2 Pohut Mix G	M27 Wineb Mix A	M30 Karam Mix G	M55 Manuk Mix E	M58 Mahoe Mix G	M83 Manuk Mix D	M86 Karam Mix F	M111 Ribbo Mix G	M114 Ti Ko Mix B	M139 Mahoe Mix C	M142 Karam Mix G	M167 Pohut Mix E	M170 Manuk Mix B	M195 Wineb Mix A	M198 Totar Mix B
M3 Pohut Mix E	M26 Wineb Mix E	M31 Karam Mix E	M54 Manuk Mix D	M59 Mahoe Mix C	M82 Manuk Mix C	M87 Karam Mix C	M110 Ribbo Mix D	M115 Ti Ko Mix C	M138 Mahoe Mix G	M143 Karam Mix E	M166 Pohut Mix A	M171 Manuk Mix D	M194 Wineb Mix D	M199 Totar Mix F
M4 Pohut Mix C	M25 Wineb Mix G	M32 Karam Mix B	M53 Manuk Mix B	M60 Mahoe Mix D	M81 Manuk Mix B	M88 Karam Mix A	M109 Ribbo Mix F	M116 Ti Ko Mix A	M137 Mahoe Mix D	M144 Karam Mix D	M165 Pohut Mix C	M172 Manuk Mix F	M193 Wineb Mix E	M200 Totar Mix C
M5 Pohut Mix D	M24 Wineb Mix C	M33 Karam Mix D	M52 Manuk Mix F	M61 Mahoe Mix F	M80 Manuk Mix A	M89 Karam Mix D	M108 Ribbo Mix C	M117 Ti Ko Mix D	M136 Mahoe Mix F	M145 Karam Mix F	M164 Pohut Mix F	M173 Manuk Mix A	M192 Wineb Mix C	M201 Totar Mix D
M6 Pohut Mix B	M23 Wineb Mix D	M34 Karam Mix A	M51 Manuk Mix A	M62 Mahoe Mix E	M79 Manuk Mix G	M90 Karam Mix E	M107 Ribbo Mix E	M118 Ti Ko Mix F	M135 Mahoe Mix A	M146 Karam Mix A	M163 Pohut Mix D	M174 Manuk Mix E	M191 Wineb Mix G	M202 Totar Mix A
M7 Pohut Mix F	M22 Wineb Mix B	M35 Karam Mix C	M50 Manuk Mix G	M63 Mahoe Mix B	M78 Manuk Mix F	M91 Karam Mix G	M106 Ribbo Mix B	M119 Ti Ko Mix E	M134 Mahoe Mix E	M147 Karam Mix B	M162 Pohut Mix G	M175 Manuk Mix G	M190 Wineb Mix B	M203 Totar Mix E
M8 Kanuk Mix A	M21 Ti Ko Mix A	M36 Narro Mix B	M49 Ribbo Mix B	M64 Totar Mix D	M77 Narro Mix G	M92 Totar Mix D	M105 Kanuk Mix A	M120 Pohut Mix A	M133 Wineb Mix G	M148 Narro Mix A	M161 Mahoe Mix D	M176 Ti Ko Mix F	M189 Ribbo Mix B	M204 Kanuk Mix B
M9 Kanuk Mix B	M20 Ti Ko Mix G	M37 Narro Mix C	M48 Ribbo Mix C	M65 Totar Mix E	M76 Narro Mix F	M93 Totar Mix E	M104 Kanuk Mix B	M121 Pohut Mix C	M132 Wineb Mix B	M149 Narro Mix D	M160 Mahoe Mix B	M177 Ti Ko Mix G	M188 Ribbo Mix F	M205 Kanuk Mix C
M10 Kanuk Mix D	M19 Ti Ko Mix C	M38 Narro Mix F	M47 Ribbo Mix A	M66 Totar Mix C	M75 Narro Mix E	M94 Totar Mix C	M103 Kanuk Mix D	M122 Pohut Mix D	M131 Wineb Mix A	M150 Narro Mix E	M159 Mahoe Mix F	M178 Ti Ko Mix D	M187 Ribbo Mix C	M206 Kanuk Mix F
M11 Kanuk Mix G	M18 Ti Ko Mix E	M39 Narro Mix G	M46 Ribbo Mix D	M67 Totar Mix B	M74 Narro Mix A	M95 Totar Mix A	M102 Kanuk Mix G	M123 Pohut Mix G	M130 Wineb Mix C	M151 Narro Mix C	M158 Mahoe Mix A	M179 Ti Ko Mix E	M186 Ribbo Mix D	M207 Kanuk Mix A
M12 Kanuk Mix C	M17 Ti Ko Mix B	M40 Narro Mix D	M45 Ribbo Mix F	M68 Totar Mix G	M73 Narro Mix B	M96 Totar Mix G	M101 Kanuk Mix E	M124 Pohut Mix F	M129 Wineb Mix D	M152 Narro Mix G	M157 Mahoe Mix C	M180 Ti Ko Mix B	M185 Ribbo Mix E	M208 Kanuk Mix G
M13 Kanuk Mix E	M16 Ti Ko Mix D	M41 Narro Mix A	M44 Ribbo Mix E	M69 Totar Mix A	M72 Narro Mix C	M97 Totar Mix B	M100 Kanuk Mix F	M125 Pohut Mix B	M128 Wineb Mix F	M153 Narro Mix F	M156 Mahoe Mix E	M181 Ti Ko Mix A	M184 Ribbo Mix A	M209 Kanuk Mix D
M14 Kanuk Mix F	M15 Ti Ko Mix F	M42 Narro Mix E	M43 Ribbo Mix G	M70 Totar Mix F	M71 Narro Mix D	M98 Totar Mix F	M99 Kanuk Mix C	M126 Pohut Mix E	M127 Wineb Mix E	M154 Narro Mix B	M155 Mahoe Mix G	M182 Ti Ko Mix C	M183 Ribbo Mix G	M210 Kanuk Mix E

Rep 4					Rep 5					Rep 6				
M224 Wineb Mix F	M225 Kanuk Mix B	M252 Manuk Mix G	M253 Pohut Mix F	M280 Narro Mix C	M281 Ribbo Mix B	M308 Kanuk Mix F	M309 Wineb Mix G	M336 Ti Ko Mix A	M337 Manuk Mix F	M364 Narro Mix A	M365 Manuk Mix E	M392 Wineb Mix E	M393 Ribbo Mix C	M420 Ti Ko Mix B
M223 Wineb Mix E	M226 Kanuk Mix G	M251 Manuk Mix F	M254 Pohut Mix B	M279 Narro Mix F	M282 Ribbo Mix D	M307 Kanuk Mix B	M310 Wineb Mix B	M335 Ti Ko Mix D	M338 Manuk Mix G	M363 Narro Mix B	M366 Manuk Mix B	M391 Wineb Mix A	M394 Ribbo Mix G	M419 Ti Ko Mix E
M222 Wineb Mix A	M227 Kanuk Mix F	M250 Manuk Mix B	M255 Pohut Mix A	M278 Narro Mix A	M283 Ribbo Mix C	M306 Kanuk Mix E	M311 Wineb Mix C	M334 Ti Ko Mix F	M339 Manuk Mix E	M362 Narro Mix F	M367 Manuk Mix G	M390 Wineb Mix F	M395 Ribbo Mix F	M418 Ti Ko Mix A
M221 Wineb Mix G	M228 Kanuk Mix E	M249 Manuk Mix E	M256 Pohut Mix D	M277 Narro Mix D	M284 Ribbo Mix F	M305 Kanuk Mix C	M312 Wineb Mix A	M333 Ti Ko Mix G	M340 Manuk Mix A	M361 Narro Mix D	M368 Manuk Mix A	M389 Wineb Mix G	M396 Ribbo Mix B	M417 Ti Ko Mix F
M220 Wineb Mix B	M229 Kanuk Mix A	M248 Manuk Mix D	M257 Pohut Mix E	M276 Narro Mix B	M285 Ribbo Mix G	M304 Kanuk Mix A	M313 Wineb Mix F	M332 Ti Ko Mix B	M341 Manuk Mix C	M360 Narro Mix G	M369 Manuk Mix D	M388 Wineb Mix B	M397 Ribbo Mix D	M416 Ti Ko Mix C
M219 Wineb Mix D	M230 Kanuk Mix D	M247 Manuk Mix C	M258 Pohut Mix C	M275 Narro Mix G	M286 Ribbo Mix A	M303 Kanuk Mix G	M314 Wineb Mix D	M331 Ti Ko Mix E	M342 Manuk Mix B	M359 Narro Mix E	M370 Manuk Mix C	M387 Wineb Mix D	M398 Ribbo Mix A	M415 Ti Ko Mix D
M218 Wineb Mix C	M231 Kanuk Mix C	M246 Manuk Mix A	M259 Pohut Mix G	M274 Narro Mix E	M287 Ribbo Mix E	M302 Kanuk Mix D	M315 Wineb Mix E	M330 Ti Ko Mix C	M343 Manuk Mix D	M358 Narro Mix C	M371 Manuk Mix F	M386 Wineb Mix C	M399 Ribbo Mix E	M414 Ti Ko Mix G
M217 Karam Mix G	M232 Ti Ko Mix A	M245 Ribbo Mix G	M260 Totar Mix D	M273 Mahoe Mix D	M288 Totar Mix B	M301 Karam Mix G	M316 Narro Mix C	M329 Pohut Mix D	M344 Mahoe Mix E	M357 Pohut Mix B	M372 Totar Mix F	M385 Mahoe Mix B	M400 Kanuk Mix A	M413 Karam Mix C
M216 Karam Mix A	M233 Ti Ko Mix D	M244 Ribbo Mix D	M261 Totar Mix E	M272 Mahoe Mix E	M289 Totar Mix G	M300 Karam Mix E	M317 Narro Mix B	M328 Pohut Mix C	M345 Mahoe Mix D	M356 Pohut Mix A	M373 Totar Mix E	M384 Mahoe Mix D	M401 Kanuk Mix G	M412 Karam Mix F
M215 Karam Mix B	M234 Ti Ko Mix E	M243 Ribbo Mix E	M262 Totar Mix F	M271 Mahoe Mix B	M290 Totar Mix D	M299 Karam Mix C	M318 Narro Mix G	M327 Pohut Mix F	M346 Mahoe Mix B	M355 Pohut Mix E	M374 Totar Mix D	M383 Mahoe Mix C	M402 Kanuk Mix D	M411 Karam Mix B
M214 Karam Mix C	M235 Ti Ko Mix F	M242 Ribbo Mix A	M263 Totar Mix B	M270 Mahoe Mix F	M291 Totar Mix F	M298 Karam Mix D	M319 Narro Mix E	M326 Pohut Mix G	M347 Mahoe Mix F	M354 Pohut Mix G	M375 Totar Mix A	M382 Mahoe Mix E	M403 Kanuk Mix C	M410 Karam Mix E
M213 Karam Mix D	M236 Ti Ko Mix C	M241 Ribbo Mix B	M264 Totar Mix A	M269 Mahoe Mix A	M292 Totar Mix A	M297 Karam Mix F	M320 Narro Mix A	M325 Pohut Mix B	M348 Mahoe Mix A	M353 Pohut Mix F	M376 Totar Mix G	M381 Mahoe Mix F	M404 Kanuk Mix E	M409 Karam Mix D
M212 Karam Mix E	M237 Ti Ko Mix G	M240 Ribbo Mix C	M265 Totar Mix G	M268 Mahoe Mix G	M293 Totar Mix E	M296 Karam Mix A	M321 Narro Mix F	M324 Pohut Mix E	M349 Mahoe Mix C	M352 Pohut Mix C	M377 Totar Mix C	M380 Mahoe Mix A	M405 Kanuk Mix B	M408 Karam Mix A
M211 Karam Mix F	M238 Ti Ko Mix B	M239 Ribbo Mix F	M266 Totar Mix C	M267 Mahoe Mix C	M294 Totar Mix C	M295 Karam Mix B	M322 Narro Mix D	M323 Pohut Mix A	M350 Mahoe Mix G	M351 Pohut Mix D	M378 Totar Mix B	M379 Mahoe Mix G	M406 Kanuk Mix F	M407 Karam Mix G