REGIONAL BIOSOLIDS STRATEGY
LOWER NORTH ISLAND

Report 6: Biosolids Processing Trials; Trial for assessing the reuse of biosolids as a growing substrate for nursery plants

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Regional Biosolids Strategy – Lower North Island

Report 6: Biosolids Processing Trials; Trial for assessing the reuse of biosolids as a growing substrate for nursery plants.

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EXECUTIVE SUMMARY

Background

Current policy and community expectations focus on the development of sustainable reuse options for biosolids. One potential use for biosolids is as part of seedling growth media in nurseries. LEI and ESR have been investigating the potential use of biosolids in this way through a greenhouse seedling trial.

Six native NZ plant species commonly grown in nurseries were chosen for this trial: *Hebe stricta* (koromiko), *Poa cita* (silver tussock), *Corokia cheesemanii*, *Phormium tenax* (harakeke or NZ flax), *Griselinia* sp. (broadleaf) and *Cordyline australis* (Cabbage tree/ tī kōuka).

The plants were exposed to increasing concentrations of four types of biosolids mixed with bark as an inert substrate. The biosolids used were fresh digested biosolids from Rosedale, Auckland, fresh digested biosolids from Whanganui (both at 0%, 5%, 10%, 15%, 25% concentrations), aged geobag biosolids from Tokomaru, and composted biosolids from Palmerston North (both at 0%, 10%, 20%, 30%, 50%).

Plants were potted into 36-well trays with one row for each biosolids concentration and one plant type per tray. Six replicates of each plant species were planted in each biosolid/bark ratio, totalling 720 planted seedlings. Plants were grown in the biosolid/bark mix for approx. four months, until they needed to be watered more than twice per day. Growth was monitored fortnightly by measuring plant height or number of leaves. At the end of the experiment, all aerial parts of the plants were harvested and dried to determine aerial dry weight.

Key Findings

Palmerston North biosolids supplied extra nitrogen (1.9 % N), phosphorus (1.3 % P) and potassium (1.0 % K), to the bark substrate, and they presented low concentration of trace elements. All plant species except broadleaf grew well up to the highest treatment and did not exhibit toxicity symptoms. The recommended ratio for these biosolids - which could be used without further treatment - is 30 % dry weight if mixed with bark.

Tokomaru biosolids did not supply extra N (0.35 %) to the bark substrate, and P (0.1 %) was only twice the concentration in bark. They exhibited high copper (Cu), and low pH, explaining why plants showed less vigour and growth than those grown in the other three biosolids. However, growth was still better than that exhibited in the control treatments. Combining these biosolids with other biosolids containing higher concentration of nutrients, and higher pH, or adding lime, would be required before use as potting mix.

Auckland (Rosedale) biosolids contained the highest levels of N (6 %), and P (2.7 %) of the four selected biosolids, and plants grew well throughout the experiment with good health and coloration. Koromiko and broadleaf grew less at the highest concentration (25% dw) of these biosolids than in the best concentration (15 % and 10 % respectively). This was attributed to the high Cu, and NH_4^+, which in combination with low K may have led to a K deficiency. Elevated *E.*

coli, Zn and Cu (higher than limits for grade "Aa" biosolids; NZWWA, 2003) would limit their use, requiring further treatment and/or mixing with other biowaste for safe use. The optimum ratio for Auckland biosolids mixed with bark was 15 % (dry weight) for the seedlings tested.

Whanganui biosolids exhibited elevated Cr (1.7%) concentration, which was above guideline limits, posing a concern for potential use. Nonetheless, all the plant species grew significantly better than the control, likely due to the supply of N (4.9 %) and P (0.9 %). The discontinuation of the discharge of the tannery effluent to Whanganui WWTP will likely reduce Cr, salinity and Na in the biosolids. These biosolids exhibited potential for use in a seedling growing mix at 15 % dry weight concentration.

Overall, all the types of biosolids (fresh and aged) that were investigated in this trial could be used in growing substrates for native NZ seedlings in nurseries.

INTRODUCTION

In the lower North Island, there is an estimated 80,000 tonnes of sludge in oxidation ponds that requires management over time. Most of this sludge which is removed from the treatment plants ends up in landfills. Landfilling is not considered to be a long-term management option and is becoming more difficult due to increased levies, space required and transportation distances. Further, there is an increasing community expectation to develop sustainable use options where the material can be considered a resource. Finding alternatives to landfilling of this sludge is especially difficult for smaller communities where limitations (due to lesser economies of scale) prevent the development of sustainable non-landfill options.

This project aims to develop a collective biosolids strategy and re-use programme in the lower North Island. The strategy will provide economies of scale and alternatives for discharge and beneficial use of biosolids which are affordable, sustainable and provide targeted solutions that are consistent with national waste minimisation strategies.

The Lowe Environmental Impact (LEI) / Institute of Environmental Science and Research Ltd (ESR) team (Project Team) are working with ten councils in the Lower North Island to determine pathways for working together that will form the basis of a regional strategy. An initial stock-take and gaps analysis determined the scale of the current sludge problem for each district; this information has been used to determine potential collective solutions including processing, end-uses, consenting and stakeholder engagement processes. Some of these potential solutions are being trialled (e.g. field trials of composting). The outcome of the project will be a 'tool box' of different scenarios that provides a model of operation that can be applied in other regions around New Zealand.

One potential end-use the Councils wish to investigate is the feasibility of using biosolids in seedling raising mixes. Many Councils have their own nurseries that produce plants for amenity plantings in their district. In addition, New Zealand has just launched a Government initiative to plant 'One Billion Trees' over the next 10 years (MPI, 2019), thus nurseries will be required to increase seedling production. However, not all New Zealand native plants have the same nutrient requirements (Franklin et al., 2015) and/or tolerance to some compounds and properties of biosolids, such as sodium, salinity or trace elements (Gutiérrez-Ginés et al., 2019). Previous experiments have demonstrated that different NZ plant species, in different soil types, responds to biosolids differently (Gutiérrez-Ginés et al., 2017).

To be able to evaluate the potential of using biosolids in seedling raising mix for growing NZ native species, LEI and ESR have undertaken a greenhouse seedling trial. The objective of this report is to present the results of the seedling trial, and outline recommendations for use biosolids in this way. This document reports on the final results of the Activity 1: 1B Biosolids Seedling Trial.

MATERIALS AND METHODS

In this experiment, we tested four contrasting biosolids from different New Zealand wastewater treatment plants. The biosolids were tested at increasing percentages mixed with a potting substrate (bark mulch), and six New Zealand native species which are commonly grown in nurseries.

Biosolids, bark substrate, and seedlings

20-25 kg of four different biosolids were obtained for the trial:

- Palmerston North (anaerobically digested and composted biosolids) - PN
- Tokomaru (pond sludge up to 60 years old, aged; geobag) - TOK
- Auckland (Rosedale/Watercare; anaerobically digested fresh) - AKL
- Whanganui (fresh anaerobically digested biosolids) - WHA

Composted bark fines, from Natural Bark & Compost (Foxton, Manawatu) were used as substrate to mix with the biosolids. The bark was chosen based on advice from the plant nursery (Garner Park, Levin) due to the low nutrient, high moisture retention properties of the bark fines.

All biosolids and bark fines were passed through a 12 mm sieve, and homogenised for 20 minutes. Subsamples of the homogenized biosolids and bark fines were collected for further analysis. Moisture content, *Escherichia coli* (*E. coli*), and presence of *Campylobacter* sp. were measured for each biosolids at the ESR-KSC laboratories, and chemical analysis were performed by Hills Laboratories (see annex).

For determining moisture content 10 g of biosolids were dried at 104 °C for 3 days (Blakemore, Searle, & Daly, 1987). *E. coli* was enumerated in 10 g of fresh biosolids using the 5-tube Most Probable Number method, and calculated per dried weight. *Campylobacter* sp. presence was tested by plating 10 µL of sludge extract in Campylobacter selective agar plates. The characteristics of the four biosolids and the bark are presented in Table 1.

The plant species used for this experiment were sourced from Garner Park nursery (Levin). They were selected as they are commonly used in amenity plantings. The plant species are the following:

1. *Hebe stricta* (koromiko) – A commonly grown re-vegetation shrub
2. *Poa cita* (silver tussock) – Native coastal grass good in dry areas
3. *Corokia cheesemanii* – A native shrub commonly used for re-vegetation
4. *Phormium tenax* (harakeke or NZ flax) - A commonly grown re-vegetation shrub
5. *Griselinia* sp. (broadleaf) – A native evergreen shrub used frequently in hedging and as an ornamental
6. *Cordyline australis* (Cabbage tree/ tī kōuka) – A native tree usually planted in gardens or revegetation areas.

Experimental set up and monitoring

Each biosolids type was mixed with bark at increasing concentrations based on dry weight, producing five treatments per biosolids type: PN, and TOK at 0%, 10%, 20%, 30%, 50%, and AKL, and WHA at 0%, 5%, 10%, 15%, 25%. Fresh biosolids were mixed at lower ratios to aged biosolids due to the greater likelihood of adverse impacts to seedlings from the less stabilised products, coupled with the greater degradation of composted and geobag bisolids.

Six replicates of each plant species were planted in each of the five biosolid/bark ratios, for each biosolids, totaling 720 plants planted. Plants were planted into biosolids/bark mixes in the PC2 laboratory before being transported to the greenhouse.

Table 1: Characteristics of the four sludge and bark used in the seedling trial. Units are expressed as dry weight. * Values for pathogens indicate limits for "Grade A" biosolids, values for trace elements, indicate limits for grades "a" - "b" biosolids (NZWWA, 2003). Shaded cells indicate parameters where biosolids are above certain limits.

Properties	Units	PN	TOK	AKL	WHA	Bark Fines	Biosolids Guidelines*
Escherichia coli	MPN/g	<53	<30	5.7 x 10^4	<23	<38	< 100
Campylobacter sp.		Present	Absent	Present	Absent	Absent	< 1 / 25g
Dry matter	%	34	61	20	79	47	-
Ash	%	61	92	28	25	42	-
pH		6.4	4.2	8.1	7.2	5.6	-
Electrical conductivity	mS/m	419	54.5	248	618	13.2	-
Organic matter	%	39	8.1	72	75	58	-
Total Organic Carbon	%	20	3.1	34	39	23	-
Total N	%	1.89	0.35	6.0	4.9	0.26	-
NH_4^+-N	mg/kg	6	240	12,500	3,700	6	-
NO_2^--N	mg/kg	<60	<1.0	<3	<1.0	<1.0	-
NO_3^--N	mg/kg	2400	3.2	<3.4	15.2	5.7	-
Ca	mg/kg	21,000	2,000	18,000	24,000	8,700	-
Mg	mg/kg	3,100	2,900	10,900	2,000	1,580	-
P	mg/kg	13,300	1,090	27,000	8,900	520	-
K	mg/kg	10,200	940	2,000	760	1,590	-
Na	mg/kg	1,550	108	720	4,200	300	-
Mn	mg/kg	350	240	139	1,170	165	-
As	mg/kg	11	5	5	5	2	20 - 30
Cd	mg/kg	0.51	0.028	0.81	0.39	<0.10	1 - 10
Cr	mg/kg	19	19	21	17,300	6	600 – 1,500
Cu	mg/kg	61	128	240	108	8	100 – 1,250
Pb	mg/kg	66	23	19.9	12.2	4.8	300
Ni	mg/kg	8	12	18	28	5	60 - 135
Zn	mg/kg	300	175	620	380	41	300 – 1,500

Plants were potted into 36-well trays with one row for each biosolids ratio and one plant type per tray, one control (bark only) row was included per tray. All plants had their roots washed to remove all potting mix before planting, roots were trimmed when they were too large to fit in the trays. Plants that had variable initial heights were trimmed to a similar starting height. All the plants were potted in approx. 150 g of bark or bark + biosolids, with the whole tray planted on the same day (Figure 1). All plant trays were evenly spread out in the greenhouse to ensure equal irrigation, with the AKL and WHA sharing one greenhouse and TOK and PN sharing another greenhouse. The plants were watered twice daily to field capacity, and trays were rotated twice weekly to avoid edge bias.

Plant growth was monitored fortnightly and height (cm) of the plants was measured. For the dicotyledons (koromiko, corokia, and broadleaf), the height was measured from the plant base to the top of the highest growing node. For the monocotyledons (silver tussock, cabbage tree, and flax), it was from the plant base to the tip of the tallest leaf.

As corokia plants were trimmed before planting on AKL, PN, and TOKO biosolids trays, plants were not developing in height but laterally. As a result, leaf count was decided as the growth indicator for these plants, as height was not representative of plant growth. Leaf counting is as reflected in the figures.

Plants were growing in the greenhouse until they size required irrigation for more than twice per day. At that stage, the experiment was harvested. This period was between 17 to 19 weeks, depending on the plant species and season (Table 2). After that period, plants were harvested by cutting and processing aerial portions. Roots and substrate were discarded. The aerial portions were washed with deionized water to remove substrate particles, and dried in the oven at 60 °C for one week. Leaves were separated from stems and both were weighed to determine biomass.

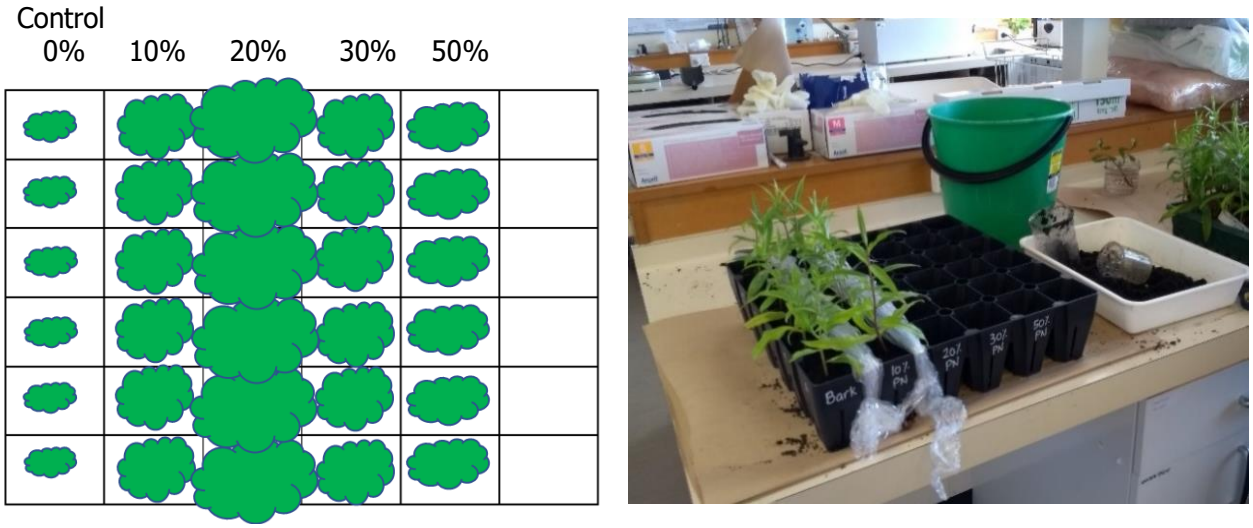

Figure 1. Left: layout of seedlings in the trays with the hypothetical optimal plant growth at medium biosolids concentration. Right: picture of the setup of the trial in the seedling trays.

Table 2: Number of weeks and period plants have grown inside the greenhouse

Biosolids	Species					
	Koromiko	Corokia	Broadleaf	Flax	Cabbage tree	Silver tussock
PN	17 Sept- Jan	17 Sept- Jan	17 Sept- Jan	17 Sept- Jan	18 Oct - Feb	17 Sept-Jan
TOK	17 Sept- Jan	18 Oct - Feb	17 Sept- Jan	17 Sept- Jan	18 Oct - Feb	17 Sept-Jan
AKL	18 Oct - Feb	18 Oct - Feb	18 Oct - Feb	18 Oct - Feb	18 Oct - Feb	18 Oct - Feb
WHA	19 Dec - Apr	19 Dec - Apr	19 Dec - Apr	19 Dec - Apr	19 Dec - Apr	19 Dec - Apr

Data analysis

Weekly growth of each plant was calculated by subtracting the initial height of the plant at potting from the weekly measured height.

A one-way analysis of variance (ANOVA) was used to determine any significant difference in growth (height in the last week and aerial biomass) between biosolid concentrations for each plant species and biosolids type. To determine which treatment was significantly different, a post hoc test was also carried out using Tukey Method. In addition, a Two-Sample t-Test was performed for comparisons between the 'best' (greatest increase in growth) and 'worst' (smallest increase in growth) biosolids concentration for each plant species per biosolids type. Minitab version 19 was used for the statistical analysis. When there were statistically significant differences between treatments, these are presented as letters in the graphs (Figures 2 to 8).

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RESULTS AND DISCUSSION

Palmerston North Composted Biosolids

The Palmerston North/bark mulch mixture was found to be an effective potting mix for the selected species, demonstrated by all six species growing well at all biosolids concentrations (Figures 2 and 3). The Palmerston North biosolids have almost 2% of total nitrogen, 1.3 % Total P and 1 % K. The inorganic nitrogen is mostly in the form of nitrate (Table 1), which is the form preferred for most plant species. At the highest biosolids concentration (50 %), flax, koromiko, and cabbage tree produced 30 %, 67 % and 300 % more biomass respectively than the mixture with 10% biosolids. Broadleaf, silver tussock and corokia did not show differences in height or biomass in the different biosolids concentrations. This indicates the low nutrient requirement of these species. None of the six species were negatively affected by the highest concentrations of these biosolids. The concentration of trace elements is not a concern for the growth of plants, and all the trace element concentrations are below limits for grade "a" biosolids for unrestricted use, according to the current guidelines (NZWWA, 2003).

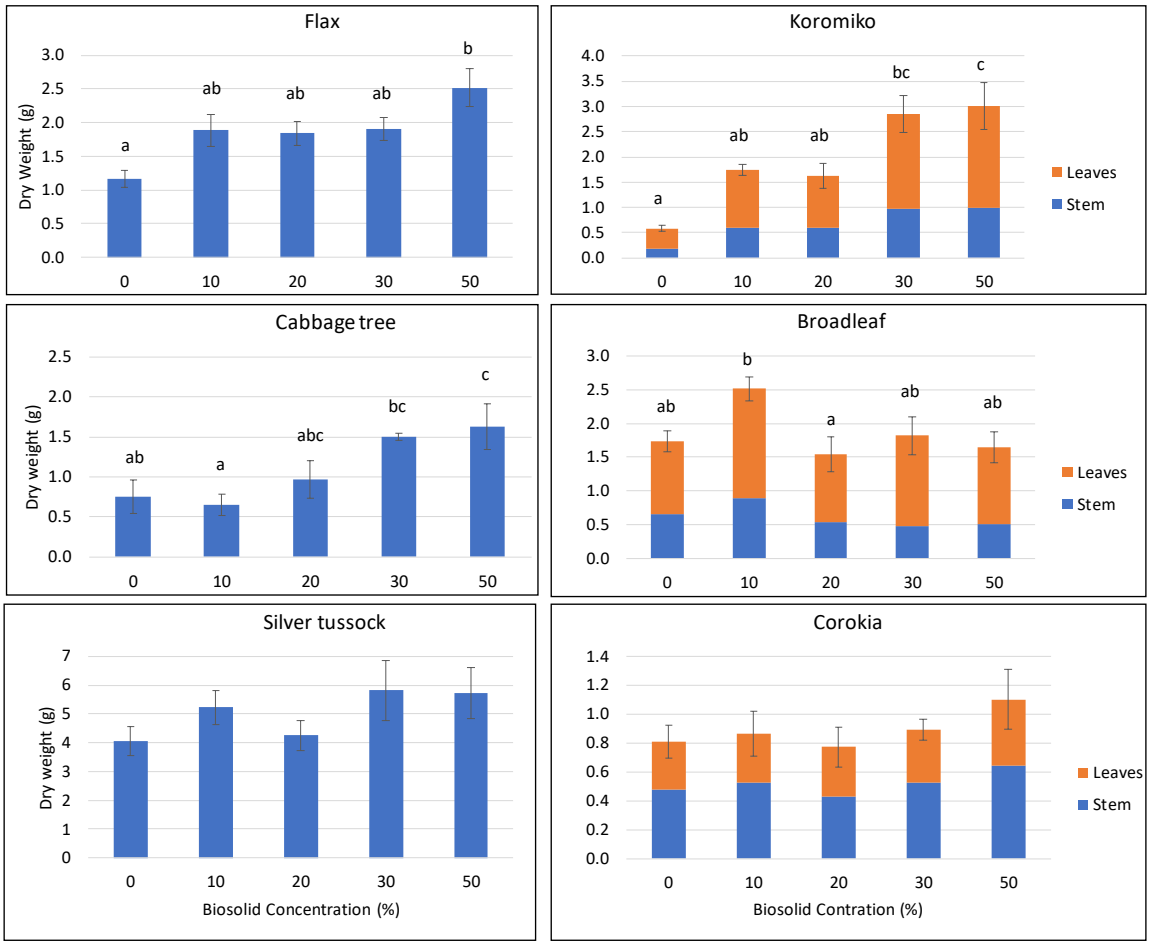

Figure 2. Average dry weight of the plants grown in increasing concentrations of biosolids from Palmerston North. Error bars indicate standard error. Different letters indicate significant differences between treatments ($p < 0.05$).

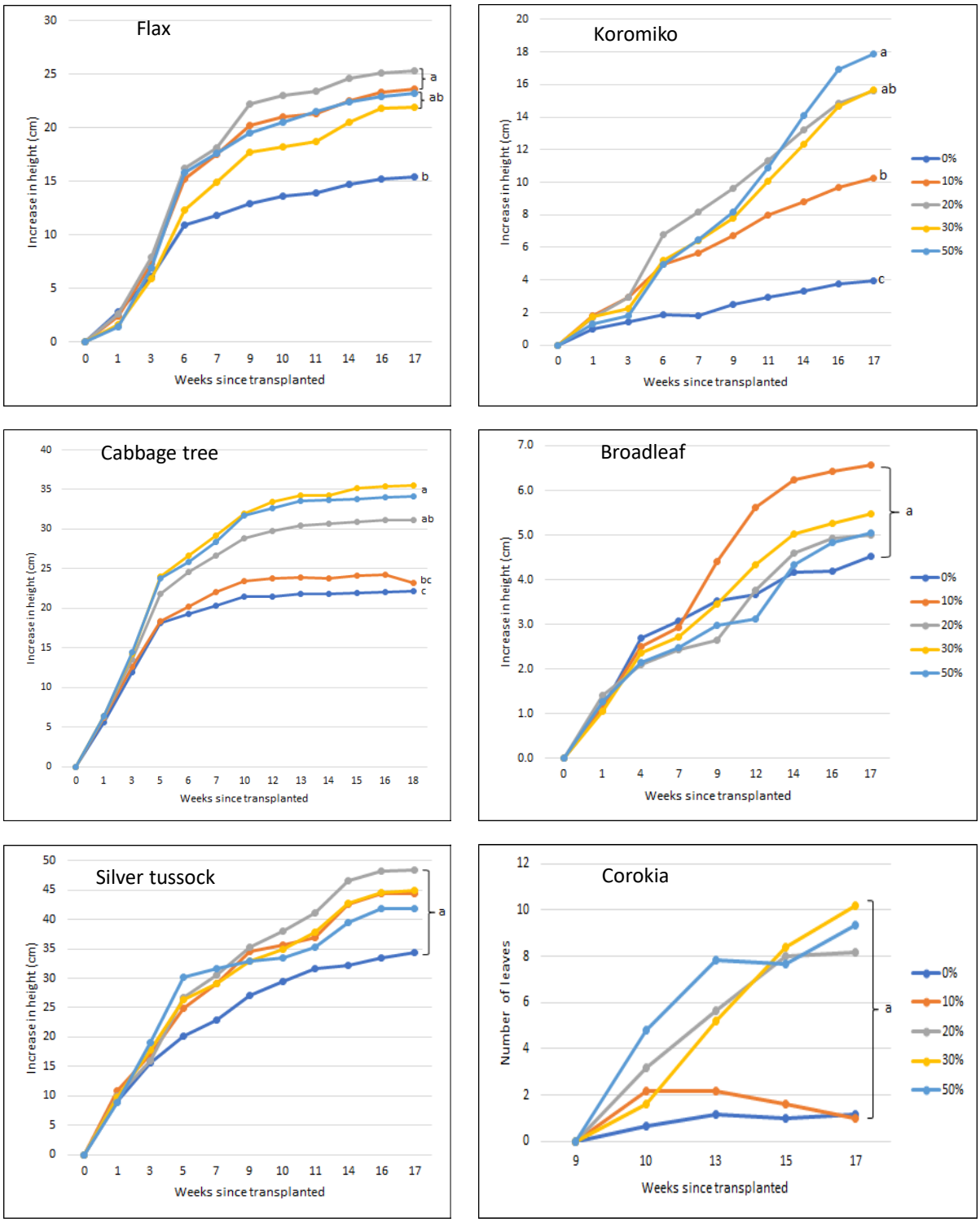

Figure 3. Growth of the species growing in increasing concentrations of biosolids from Palmerston North throughout the experiment. Results show averages. Different letters indicate significant differences between treatments in the last week of monitoring ($p < 0.05$).

Tokomaru Aged Geobag Biosolids

The chemical properties of the biosolids from Tokomaru were not found to be optimal for plant growth (Table 1), because these biosolids hardly supplied extra nutrients to the mixture with bark, with concentration of N, P and K at just 0.35%, 0.1% and 0.09% respectively. In addition, the concentration of Cu (128 mg/kg) in combination with very low pH (4.2) is considered toxic for plants (Kabata-Pendias & Mukherjee, 2007). This is reflected by the variable responses of plant growth and vigour throughout the experiment (Figures 4 and 5). Flax and silver tussock did increase in height with addition of biosolids (best rate was 20% for flax and 10% for silver tussock), but results of biomass did not show significant differences. Cabbage tree and broadleaf produced significantly more biomass at the highest concentration of biosolids (50%), but there was no difference in height (not significant). Corokia did not show any difference in growth with contrasting concentration of biosolids. Only koromiko consistently grew better (height and biomass) with increasing biosolids concentration, up to 50 %. However, throughout the experiment, the koromiko leaves were notably chlorotic (pale green – yellow colour) compared with the other types of biosolids (see annex). This is consistent with better growth with the slight increase of N and P, but Cu toxicity at the highest concentration. It was evident that these biosolids were not highly suitable for use as potting mix, and in fact were detrimental for silver tussock at the highest concentrations.

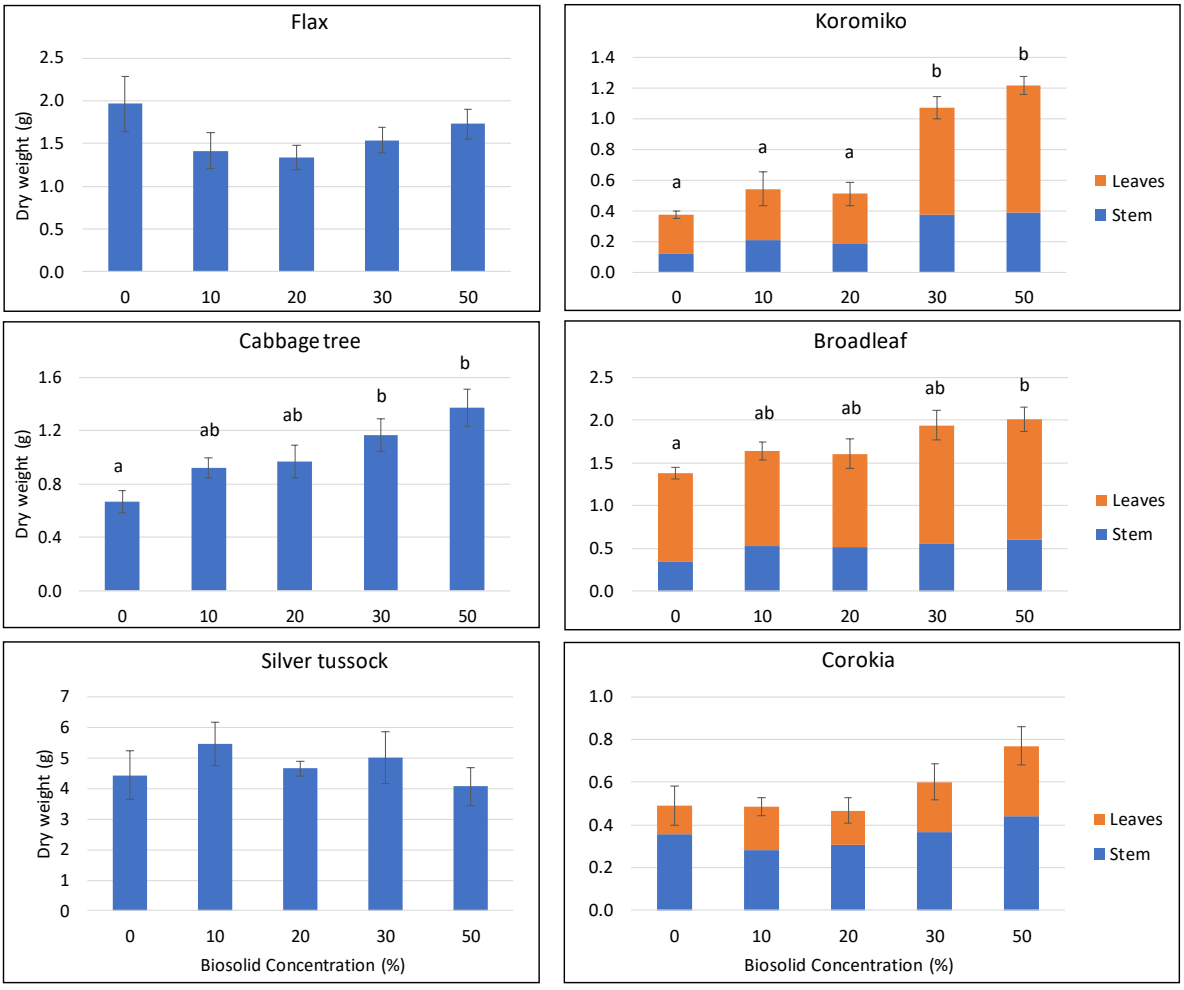

Figure 4. Average dry weight of the plants grown in biosolids from Tokomaru. Error bars indicate standard errors. Different letters indicate significant differences between treatments ($p < 0.05$).

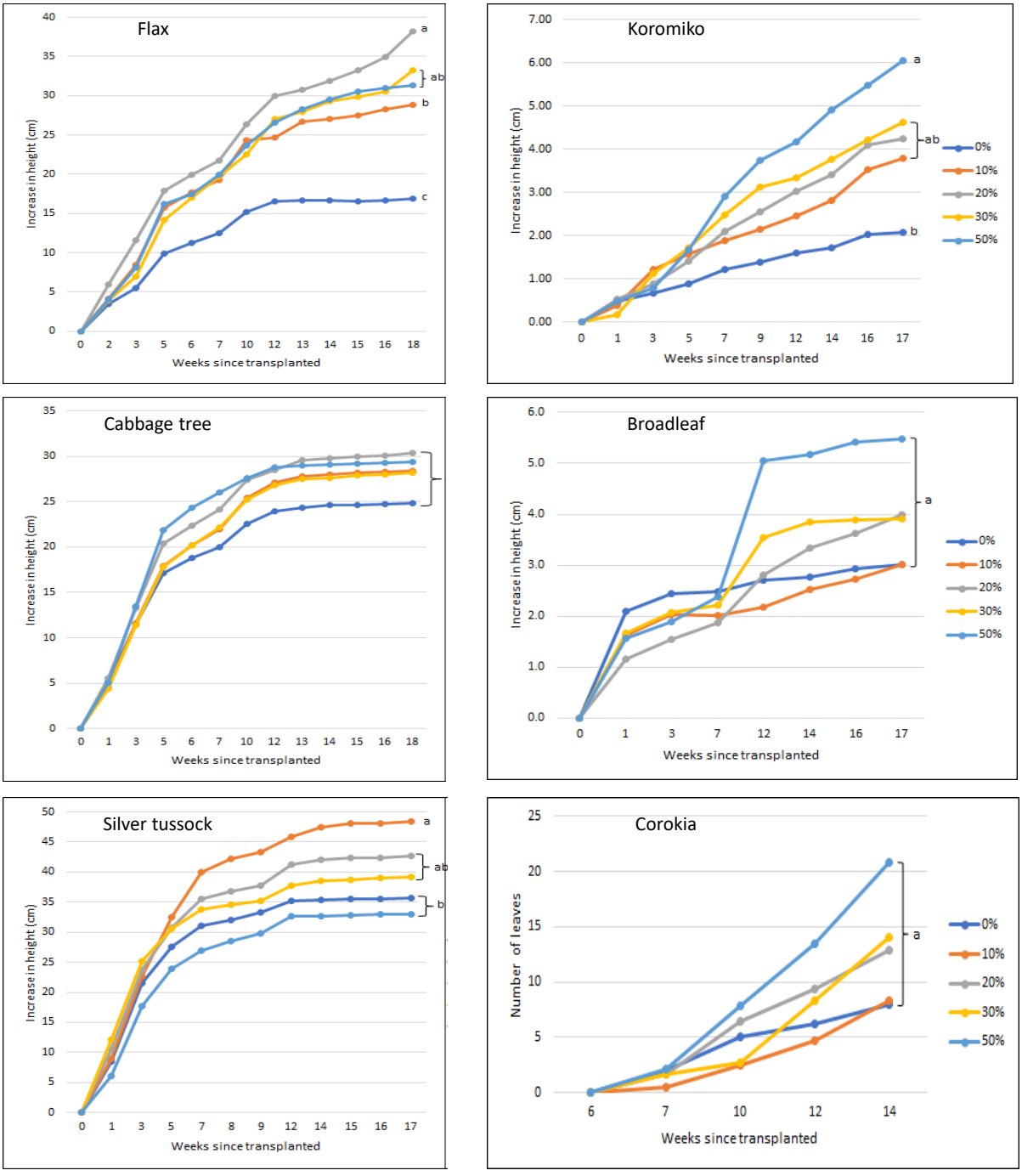

Figure 5. Growth of the species growing in increasing concentrations of biosolids from Tokomaru throughout the experiment. Results show averages. Different letters indicate significant differences between treatments in the last week of monitoring ($p < 0.05$).

Auckland Fresh Biosolids

All plant species grew well in Auckland biosolids mixed with bark fines (Figures 6 and 7). These biosolids have high concentration of nutrients (6 % of N, and 2.7 % of P), which explains the healthy appearance of all plant species (see annex), in comparison with other biosolids. Moreover, koromikos planted in these biosolids (10%, 15%, and 25%) flowered in week 13. However, the highest concentration of these biosolids (25 %) led to reduced height of broadleaf, compared with the 10 % biosolids treatment. This is potentially caused by the high concentration of Cu (240 mg/kg), which is at a potentially toxic concentration for plants (Kabata-Pendias & Mukherjee, 2007), although the high pH (8.1) will help reduce Cu availability and blending with bark fines significantly reduces concentrations to below guideline limits. It is possible that high NH_4^+ (1.2 %) may have had negative effects for some plants, due to induced K deficiency (Maathuis & Sanders, 1996). *E. coli* numbers, and concentration of Zn and Cu over the limits for "Aa" grade biosolids indicates that these biosolids will need to be used with certain restrictions or further treatment. However, as mentioned blending is considered a suitable means for reducing/diluting chemical contaminants to within safe levels and is the case with use in the manner described. In addition, given the high nutrient concentration of this biosolids only a small addition would be required as fertiliser, further reducing the final concentration of trace elements in the resulting mixtures via dilution.

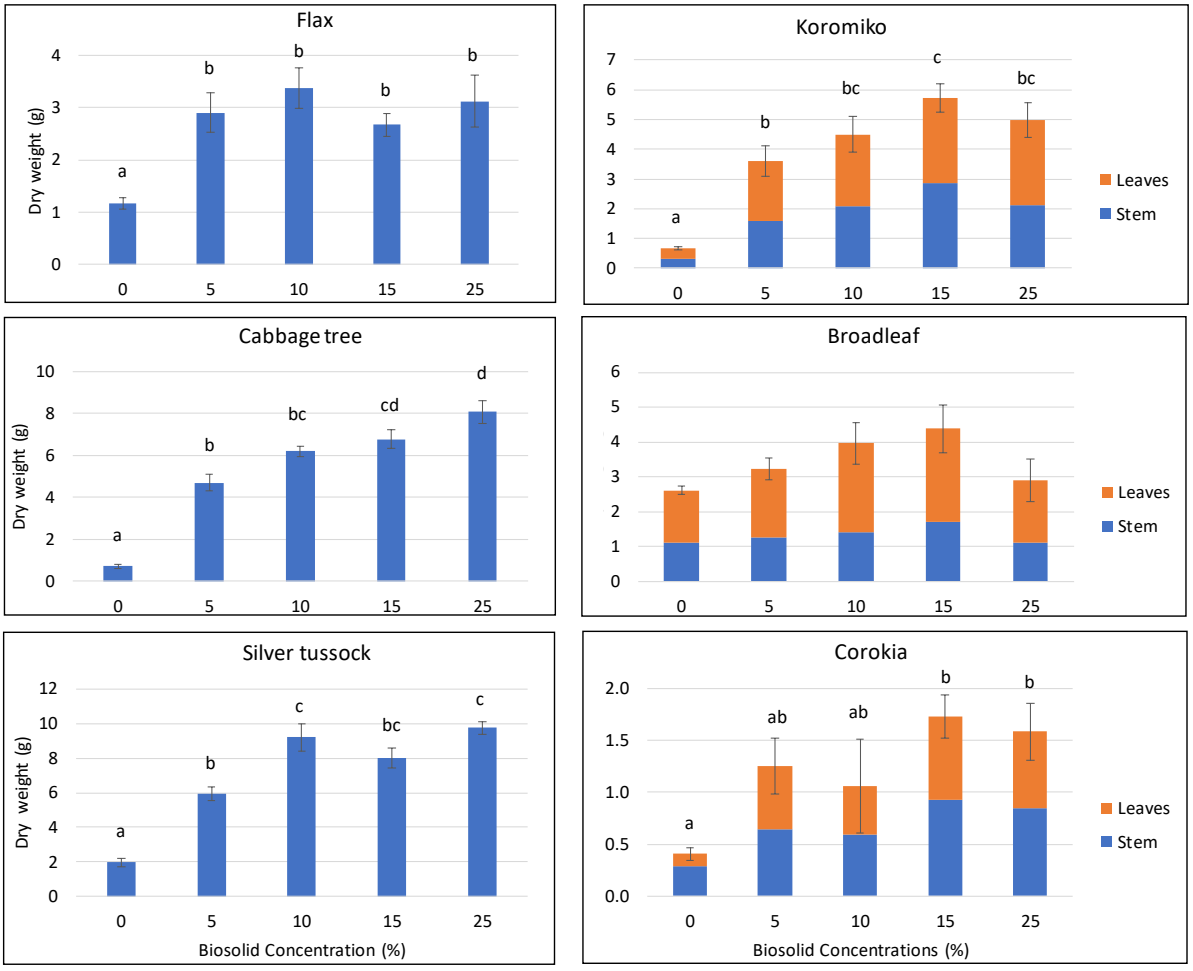

Figure 6. Average dry weight of the plants grown in biosolids from Auckland. Error bars indicate standard errors. Different letters indicate significant differences between treatments ($p < 0.05$).

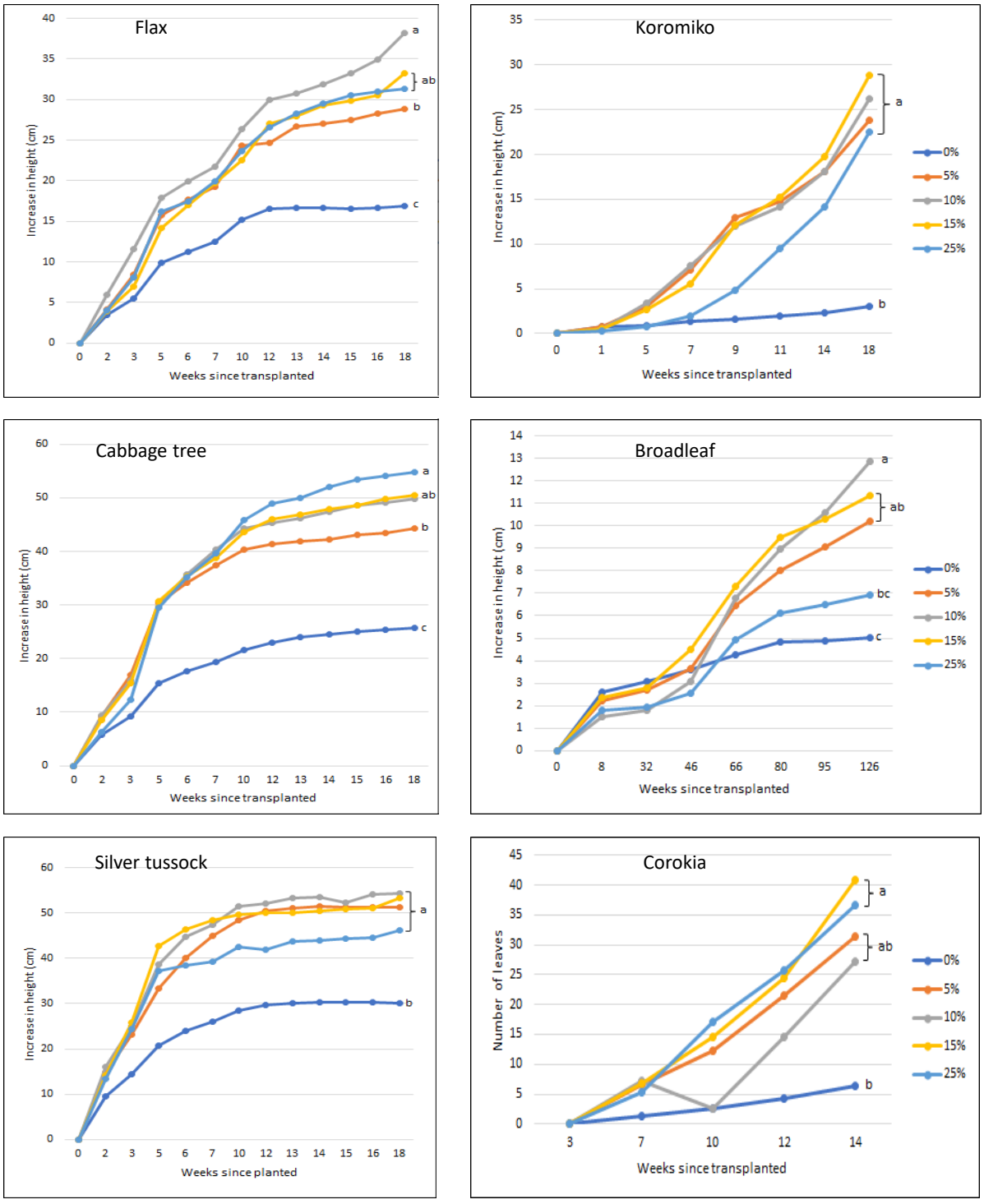

Figure 6. Growth of the species growing in increasing concentrations of biosolids from Auckland throughout the experiment. Results show averages. Different letters indicate significant differences between treatments in the last week of monitoring ($p < 0.05$).

Whanganui Fresh Digested Biosolids

It can be seen in Figures 7 and 8 that all the plant species treated with Whanganui biosolids grew well. These biosolids contain adequate concentrations of N (4.9 %), and P (0.89 %), with relatively low K (0.07%). The highest concentration of these biosolids did not cause a significant decrease in biomass, but reduced the height of broadleaf and corokia compared to lower concentrations of biosolids. In addition, silver tussock developed chlorosis during the growth period at 25 % biosolid concentration and had an unhealthy appearance, especially when compared with other silver tussocks grown in other types of biosolids. This is likely due to the high concentration of Cr in these biosolids (1.7 %), which indicates an industrial contribution to the wastewater treatment plant. Chromium is known to have toxic effects on plant growth and development, photosynthesis, and uptake of a variety of nutrients, which may affect the total dry matter production and yield (Shanker, et al., 2005). Concentrations of Cu and Zn in the Whanganui biosolids are also slightly over the limit for grade 'a' biosolids (NZWWA, 2003), although, these levels are not likely to have caused the observed effects. Concentration of Na (4,200 mg/kg) and high salinity (618 mS/m) could also negatively affect the health of the plants (Abrol, et al., 1988). The source of the Cr in the Whanganui biosolids was determined to be from the addition of tannery effluent to the WWTP. Future plans to stop the use of the municipal WWTP for the treatment of this will reduce the levels of Cr, and likely the salinity and Na in the biosolids.

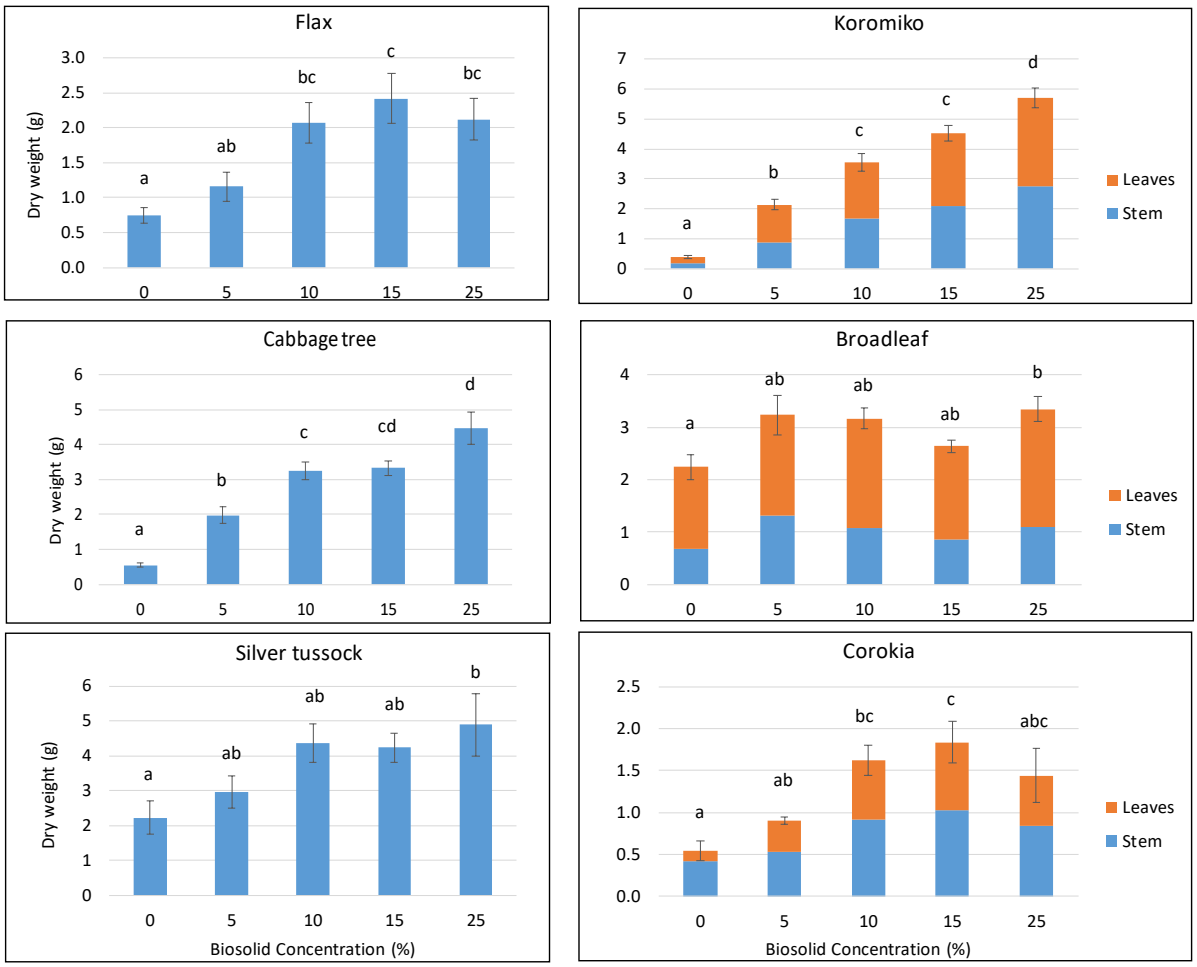

Figure 7. Average dry weight of the plants grown in biosolids from Whanganui. Error bars indicate standard errors. Different letters indicate significant differences between treatments ($p < 0.05$).

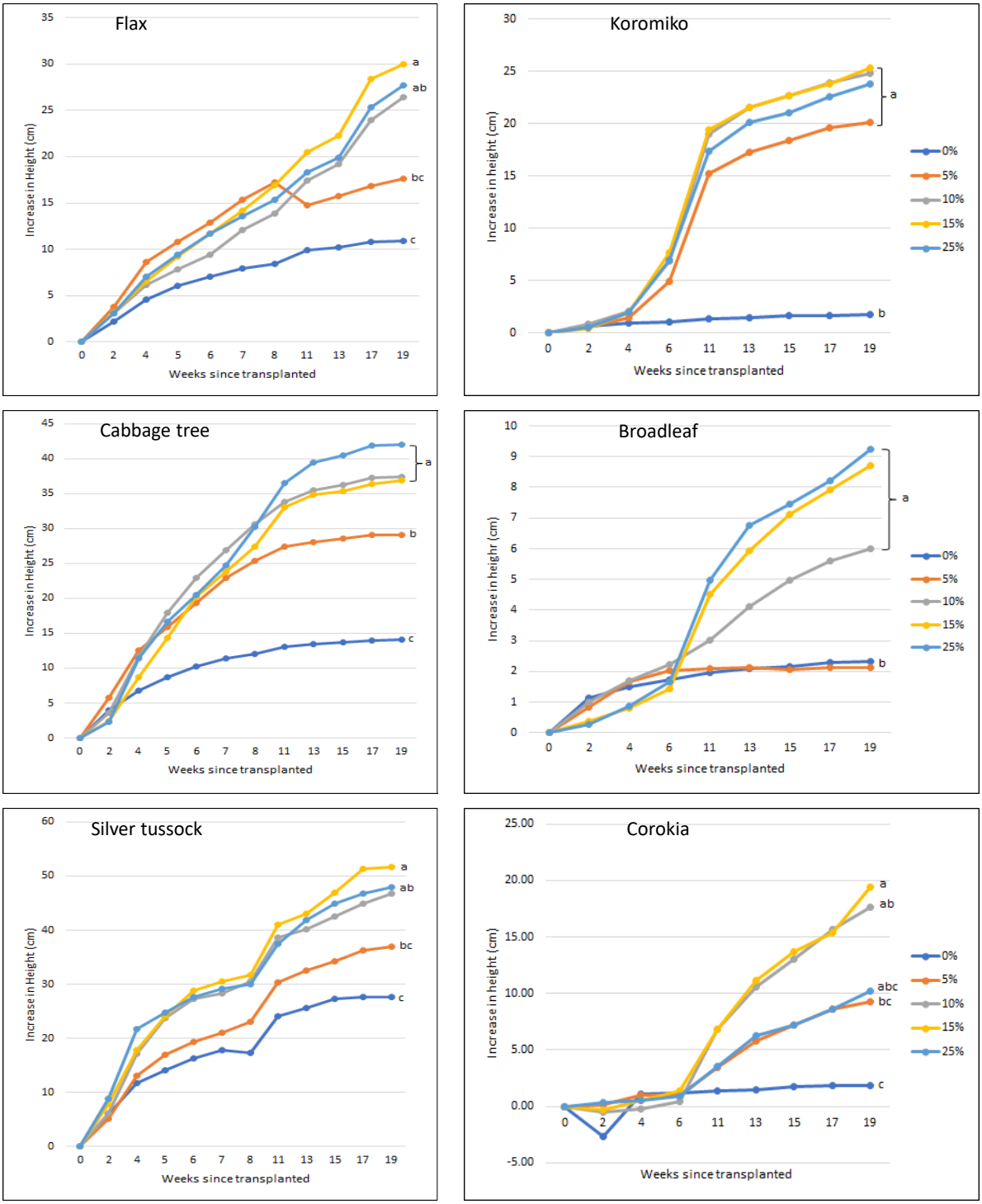

Figure 8. Growth of the species growing in increasing concentrations of biosolids from Whanganui throughout the experiment. Results show averages. Different letters indicate significant differences between treatments in the last week of monitoring ($p < 0.05$).

Limitation of the results

Although the results of this experiment indicate the potential for use of biosolids as growing substrate for native plants in nurseries, the study presents some limitations that need to be highlighted. The experiment ran between September 2018 and April 2019, but plants were planted and harvested at different times, based on when the biosolids were received. In particular, there was a delay in receiving the Whanganui biosolids, which meant that these plants were growing from mid-summer to autumn, whilst the rest of plants grew during spring and early-summer. This potential error was addressed by setting a control treatment (bark without biosolids) in each tray. This allowed the comparison of growth of the same plant in different rates of one biosolid, but not between biosolids.

Another significant limitation is the potential spatial variation of results depending on where the plant was located in the tray and in the greenhouse. Using seedling trays made plants grow closely together which may have meant that: i) not all plants received the same amount of water depending on their position in the tray, and ii) most of the trays exhibited an edge effect, plants situated in the centre of the tray grew higher than plants in the borders, potentially caused by light competition. The edge effect may influence the determination of the optimum biosolid concentration, as the middle biosolids concentration would exhibit the tallest plants. The effect of irrigation was evident in some trays where plants died of drought (10 corokia plants in AKL biosolids died, which reduced the number of replicates available). Similarly, may be an effect of "tray" as it is evident in Figure 9. This figure represents the average dry weight of all plants grown in the control treatment (bark without biosolids), the only difference being the tray where they grew. It is evident that the same treatment in different trays produced different growth. This might be caused by location in the greenhouse - even if the plants were rotated twice weekly -, time of planting, or competition caused by neighbour plants. This effect is most evident in silver tussock and broadleaf, which might partially explain why the effect of biosolids in these plants is so different among biosolids. Totally randomised placement of treatments would have eliminated this bias, although regular monitoring with pictures would not have been possible.

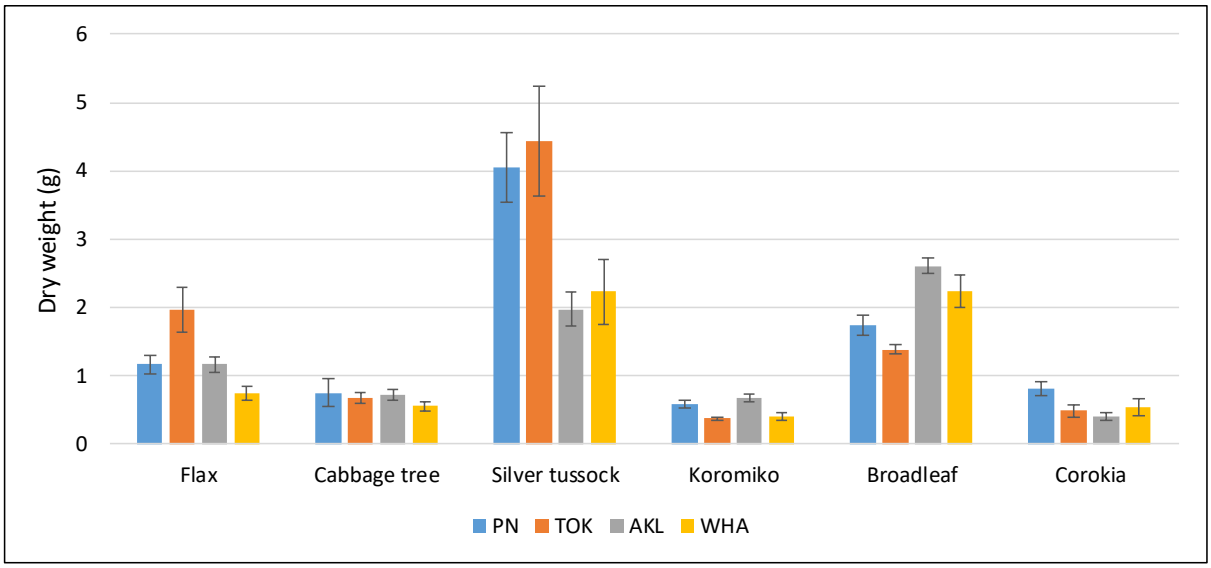

Figure 9. Dry weight (average and standard errors) of the plants grown in control treatment in each tray.

CONCLUSIONS AND RECOMMENDATION

All the types of biosolids (fresh and aged) that were investigated in this trial could be used as a growing substrate for seedlings in nurseries, as summarised in Table 3. When an optimal concentration of biosolids is used plant height and biomass are increased between 2 and 10 fold compared with control.

Table 3: Best (√) and worst (x) mixture of biosolids and bark for the biomass production of each plant species. Significant differences ($p < 0.05$) between both are represented as *.

Species	PN			TOK			AKL			WHA		
	√	x		√	X		√	x		√	x	
Flax	50	0	*	0	20		10	0	*	15	0	*
Cabbage tree	50	10	*	50	0	*	25	0	*	25	0	*
Silver tussock	30	0		10	50		25	0	*	25	0	*
Koromiko	50	0	*	50	0	*	15	0	*	25	0	*
Broadleaf	10	20	*	50	0	*	15	0		25	0	*
Corokia	50	20		50	20	*	15	0	*	15	0	*

Biosolids from **Palmerston North** have adequate concentration of N, P and K, (2%, 1.3%, and 1 % respectively), and low concentration of trace elements. All the plants grew well and healthy in these biosolids, and did not show any symptoms of toxicity. Biosolids from **Tokomaru** have low concentration of nutrients, which may be the cause of the plants showing less vigour and growth than those grown in other biosolids. The high Cu concentration in combination with low pH is likely negatively impacting the health of the plants, which showed some chlorosis. Mixing these biosolids with others with higher concentration of nutrients, and higher pH, or adding lime, would be required for using these as potting mix. Biosolids from **Auckland** have high concentration of N (6 %), and P (2.7 %), and plants grew well throughout the experiment and showed good health and coloration. The highest concentration of these biosolids was deleterious for koromiko, and broadleaf, probably due to high Cu, or high NH_4^+, which in combination with low K may lead to a K deficiency. *E. coli* numbers limits the use of these biosolids, as a potting mix directly handled by nursery workers. Chromium is the main concern in biosolids from **Whanganui**. Although we do not know the speciation of Cr - which could be Cr^{+3}, or very toxic Cr^{+6} - 1.7% is very high concentration for these biosolids to be used a substrate for growth in nurseries, other end-uses should be considered. Nonetheless, all the plant species treated with Whanganui biosolids grew significantly better than the control, likely because they contain adequate levels of N and P. Future plans to stop the use of the municipal wastewater treatment plant for the treatment of the tannery effluent will reduce the levels of Cr, and likely the salinity and Na in the biosolids.

In general, biosolids from Palmerston North could be used mixed with a substrate for creating a growing mix in nurseries. With extra management, Auckland and Whanganui biosolids have good potential also. Biosolids from Tokomaku would need a supplement of organic matter and nutrients, maybe by blending with other biosolids, and treatment with lime. Different plants require different concentrations and ratios of N:P:K for optimum growth. The optimum concentration of biosolids should therefore be assessed based on specific applications. Other

factors such as pH, salinity, and trace elements should be considered too. In general, as a safe option for all plant species, we could recommend 30 % of PN biosolids, and 15 % of AKL, and WHA biosolids when mixed with mulched bark.

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APPENDICES

Appendix A Photos of seedlings growing in the biosolids/bark mixtures in the end of the experiment

Appendix B Reports of the biosolids and bark analysis by Hills Laboratories

APPENDIX A

Photos of seedlings growing in the biosolids/bark mixtures in the end of the experiment

Figure A.1. Plants growing in different treatments with biosolids from Palmerston North in the end of the experiment.

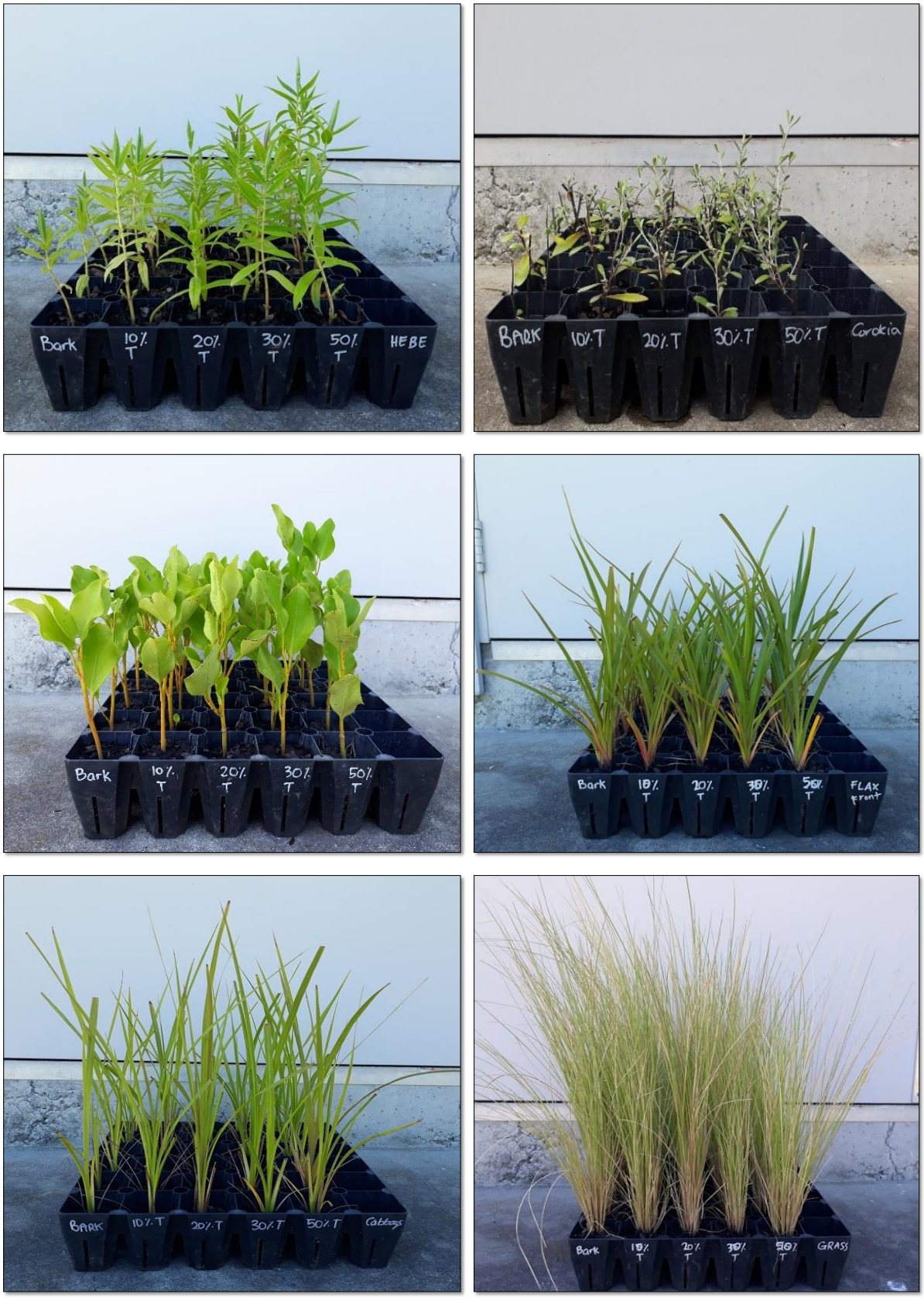

Figure A.2. Plants growing in different treatments with biosolids from Tokomaru in the end of the experiment.

Figure A.3. Plants growing in different treatments with biosolids from Auckland in the end of the experiment.

Figure A.4. Plants growing in different treatments with biosolids from Whanganui in the end of the experiment.

APPENDIX B

Reports of the biosolids and bark analysis by Hills Laboratories


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DISTRICT COUNCIL


WHANGANUI
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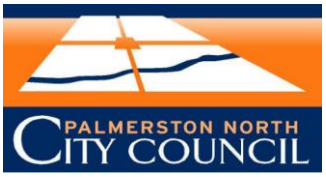
horizons
regional council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