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Evaluation of koi carp as a fertiliser for establishing native sand binders on coastal dunes in the Waikato region – first year trials

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Prepared by:
David Bergin & Michael Bergin
Environmental Restoration Ltd

For:
Waikato Regional Council
Private Bag 3038
Waikato Mail Centre
HAMILTON 3240

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Peer reviewed by:	Name	Bruno David
	Date	September 2016

Approved for release by:	Name	Alan Saunders
	Date	February 2018

Acknowledgement

Sam Stephens, formerly Biodiversity Officer Coastal, Waikato Regional Council, initiated the evaluation of koi carp as a fertiliser as a potential alternative to the standard use of artificial fertiliser in Beachcare planting programmes in the Waikato region. Dr Bruno David, Freshwater Scientist Waikato Regional Council, and Moniqua Nelson-Tunley, Site Restoration Advisor, Waikato Regional Council, provided the project brief, resources and sites to undertake the fertiliser trials. Karen Opie, Beachcare Coordinator for Waikato west coast and the Port Waikato Beachcare group planted the Port Waikato trials and assisted with monitoring and maintenance. Support from the owners of Nukuhakari Station is also acknowledged including access to the site and farm-based accommodation. Jim Dahm, Beachcare contractor for Waikato Regional Council, organised the plants and the site for the Buffalo Beach planting and coordinated the Whitianga Community Beachcare Group to assist in planting the Whitianga trial. Bruno David contracted Hill Laboratories to undertake laboratory analysis of the koi carp fertiliser.

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Abstract

Exotic koi carp (*Cyprinus carpio*) have become a major pest in freshwater systems of the lower Waikato since introduction. They contribute to poor water quality destroying native plant and fish habitat. The Waikato Regional Council have been trapping large numbers of carp and "digesting" them into a nutrient-rich dry powdery substance that has potential uses in environmental restoration including as a fertiliser in Beachcare planting programmes.

Beachcare groups in the Waikato region are involved in planting tens of thousands of the native sand binding species spinifex (*Spinifex sericeus*) and pingao (*Ficinia spiralis*) on foredunes. Planting trials were established at three Waikato beaches comparing application of koi carp fertiliser in the form of pellets with the current standard practice of NPK slow-release fertiliser tablets.

Based on growth performance up to 8 months after planting, results indicate that koi carp fertiliser gives a similar boost to growth of sand binders as the commonly used slow-release fertiliser tablets. The substantial boost in growth by koi carp compared to non-fertilised plants is consistent with previous research. There was only a small increase in growth performance for spinifex with higher rates of fertiliser and there may be a small difference in the slow-release effect between koi carp and tablet fertiliser. A second series of planting trials is recommended to confirm and refine results.

1 Introduction

Koi carp are an invasive pest fish thought to have been accidentally imported into New Zealand in the 1960s. This noxious species resemble goldfish growing to 10kg and 75cm in size. They are now widespread in Auckland and Waikato regions and are spreading into Northland, southern North Island and Nelson/Marlborough. Numbers have exploded in the rivers and lakes of the lower Waikato basin over the last 3 decades where they cause catastrophic habit loss for native fauna and flora and have a detrimental effect on water quality.

The Waikato Regional Council have been exploring the potential for a Carp-N Neutral project aimed at trapping carp and "digesting" them into fertiliser and other products to benefit environmental programmes (http://www.waikatoregion.govt.nz/Services/Regional-services/Plant-and-animal-pests/Aquatic-pests/CarpN-Neutral-Project/). (Figure 1)

There are a range of potential uses for digested carp in community-based environmental restoration programmes. Preliminary investigation indicates it performs at least as well as commercial slow-release fertiliser tablets in Beachcare planting programmes. Other potential uses include propagation of native plants, animal repellents applied to foliage, and lures in bait stations for trapping bird predators.

This project investigated the feasibility of using koi carp as a fertiliser in community-based dune planting on sand dunes undertaken as part of Beachcare programmes on east and west coasts of the Waikato region. The performance of the two key native sand binders spinifex (*Spinifex sericeus*) and pingao (*Ficinia spiralis*) up to 8 months after planting is provided comparing koi carp fertiliser in the form of pellets with the current standard practice of NPK slow-release fertiliser tablets.

Figure 1: Processing of captured pest freshwater fish koi carp into fertiliser (Waikato Regional Council)

1.1 Dune restoration

Sand dunes are amongst our most modified ecosystems in New Zealand that are a major focus of local authorities, the Department of Conservation, and community Coast Care and Beachcare groups for restoration of indigenous flora and fauna. Coastal dunes are a national priority ecosystem (NZ Coastal Policy Statement 2010). The trend in loss of indigenous biodiversity and natural dune form and function is continuing due to pressure from coastal development, spread of weeds, rabbit browsing, predation by rodents, and increasing uncontrolled recreational use. This degradation will be further exacerbated with expected impacts of climate change including increasing sea level rise and intensity of storms.

Beachcare groups in the Waikato region in collaboration with the Waikato Regional Council, landowners, district councils and the Department of Conservation have been involved in planting, weed and pest animal control and managing use of their dunes for over two decades (Figure 2). This involves planting tens of thousands of the native sand binding species spinifex and pingao on foredunes. Early planting trials by the Dune Restoration Trust of New Zealand clearly showed the benefits of incorporating slow-release NPK fertiliser at planting in restoration of foredune vegetation (refer Dunes Trust website www.dunestrust.org.nz; Bergin and Herbert 1998; Bergin 1999). Standard practice in recent years has been the application of a 10g NPK slow-release fertiliser tablet.

These planting trials at selected beaches within the Waikato region compare performance of digested koi carp organic fertiliser with slow-release fertiliser tablets used in foredune plantings.

Figure 2: **Tens of thousands of sand binders are planted by Beachcare groups per year on Waikato beaches where slow-release fertiliser tablets are used to boost early growth. This is the Whitianga Beachcare working bee planting the trial site.**

1.2 Nutrient on dunes

Research indicates that coastal dunes are likely to have had substantial inputs of nutrients from breeding and resting of seabirds and seals in the past (Hawke and Newman 2007). Human-induced decline in these animals over the last one or more centuries is likely to be a factor in reduced nutrients along with vegetation disturbance. It is considered that marine-derived nutrients introduced to dunelands could have significant positive effects on plant growth as well as benefiting associated fauna (Gardner-Gee et al. 2008). While there are some off-shore island restoration programmes considering how to increase nutrient inputs by increasing seabird populations, use of slow-release fertiliser applied at planting to boost establishment and early growth of natives on sand dunes is a practical option for current large-scale mainland Beachcare groups.

Slow-release fertilisers comprise a range of chemicals including N, P and K, all of which can potentially benefit growth of plants on sand dunes. However, nitrogen (N) is considered to be a major limiting factor on sand dunes, and while a substantial proportion of dune research on nutrient deficiency has been carried out on establishment of pines on sand dunes, there are numerous papers to support the importance of N. For example:

- *Chronic nitrogen deficiency is the only nutritional factor known to characterise all unstable coastal sand in New Zealand (Hunter et al. 1991).*
- *Recently-formed sand dunes contain very little nitrogen, and most of this is unavailable for plant growth (Gadgil 1983).*
- *Exclusion of lupins from the ecosystem resulted in lowered productivity of the pines due to slow growth rates associated with symptoms of nitrogen deficiency (Gadgil et al. 1984; Beets & Madgwick 1988).*

Therefore, for the purposes of this trial, the proportion of total nitrogen in fertiliser formulations has been selected as the key element in fairly comparing application of koi carp fertiliser with the standard fertiliser tablets. For these trials the fertiliser tablets were sourced from The Native Plant Nursery (formerly known the Taupo Native Plant Nursery (http://www.tauponativeplant.co.nz/).

1.3 Sites

A minimum of 3 sites in the Waikato region were selected to evaluate koi carp fertiliser for boosting growth of the major native sand binding species spinifex and pingao (Figure 3). The sites were:

- Nukuhakari Station, west coast, Waikato;
- Port Waikato, west coast, Waikato; and
- Whitianga, eastern Coromandel Peninsula.

Full-scale replicated trials with non-fertilised controls were established at Nukuhakari Station which is a typically exposed west coast site, as well as at Port Waikato but on a less exposed landward dune site. Koi carp and standard formulation fertiliser tablets were compared in large block plantings established as part of Beachcare community plantings at the Whitianga site.

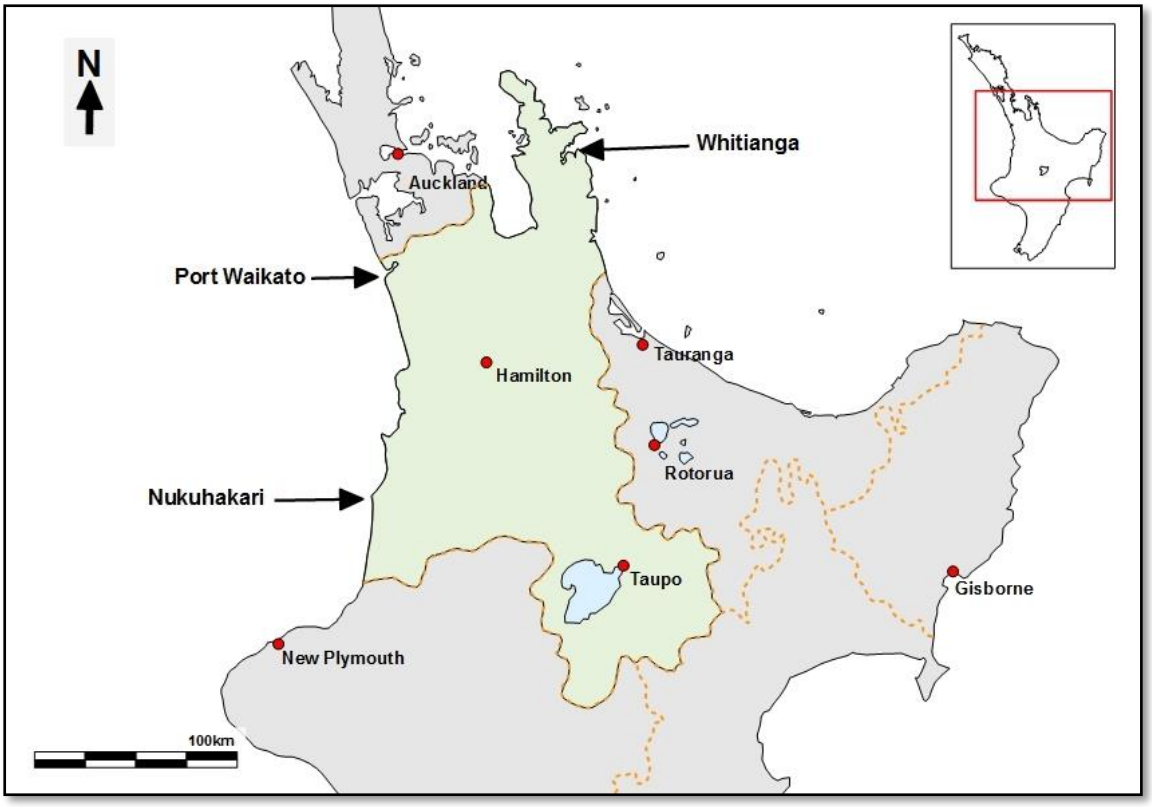


Figure 3: **The three selected coastal dune sites where the Waikato Regional Council are supporting local Beachcare groups and landowners in establishment of native sand binders on foredunes and where koi carp fertiliser trials were established**

1.4 Site description

Nukuhakari

Nukuhakari Station is a large sheep and cattle farm located on the west coast north of Awakino and south of Marokopa Beach. It has landward migrating dunes lacking in vegetation cover associated with three bays exposed to the prevailing westerly winds (Figure 2). Stock access over many years has led to serious degradation and wind erosion, with extensive mobile sand dunes now covering several hectares comprising both frontal and backdune environments.

Ngararhae Bay (Middle Bay) comprises two actively moving sand dune sheets that dominate the local landscape covering an area of over 30 ha where wind-blown fine, black sands are engulfing pasture landward (Figure 5). The fertiliser trials were established along the foredune some 20m above the high water mark at the southern portion of the dune field. The fertiliser trial was established in the vicinity of earlier dune plantings along the foredunes undertaken by Waikato Regional Council in collaboration with the station owners from 2013 onwards.

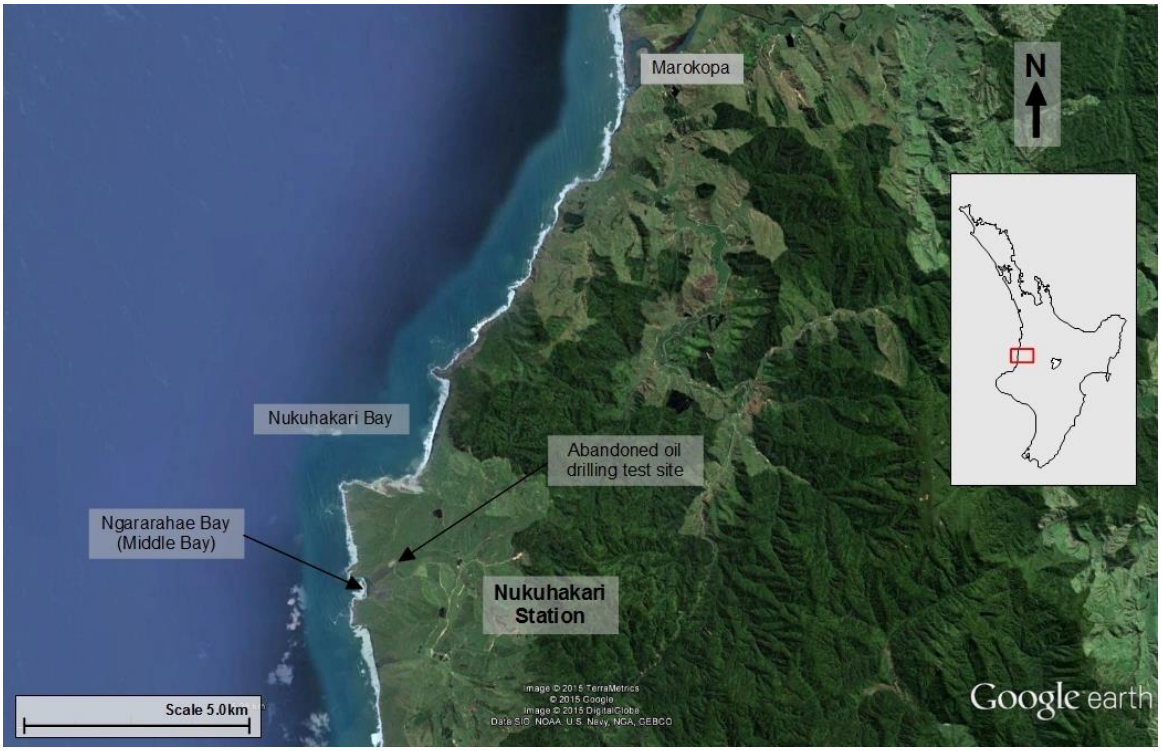


Figure 4: **Ngararahae Bay (also known as Middle Bay) where the koi carp fertiliser trial was established as part of larger scale fordune plantings by the Waikato Regional Council and landowners from 2013**

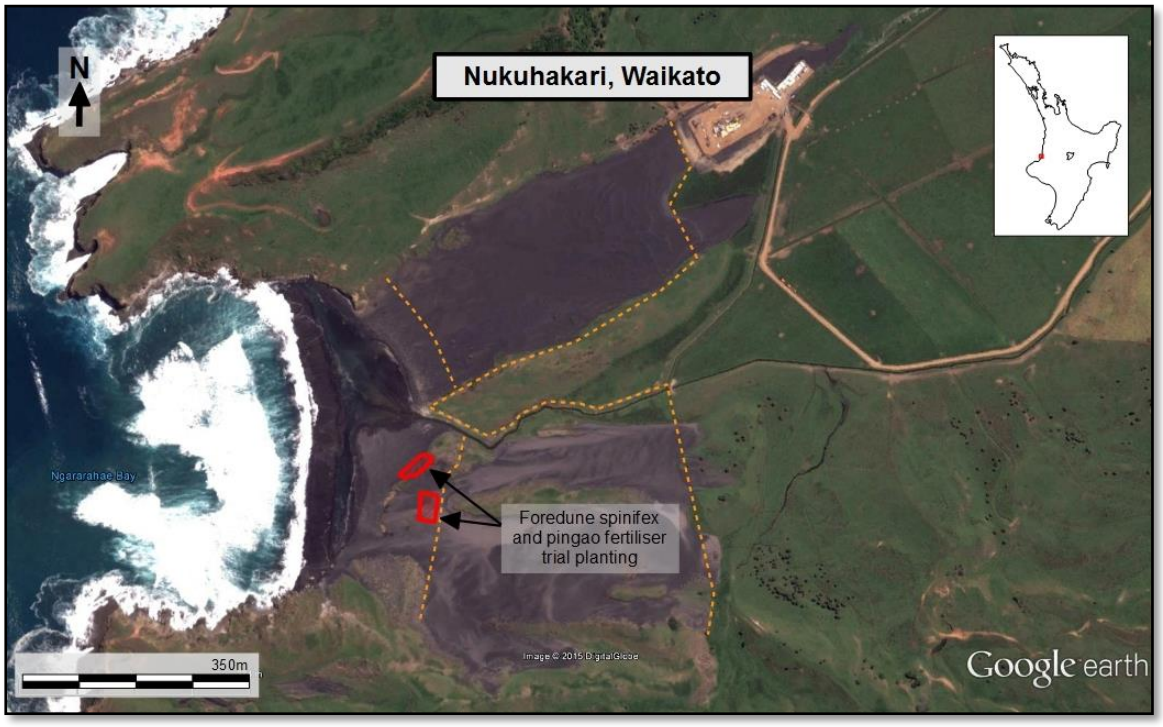


Figure 5: **Location of the spinifex and pingao foredune planting trials comparing fertiliser types at Nukuhakari Station, west coast North Island**

Port Waikato

The Port Waikato Beachcare community group is involved in a range of projects aimed at enhancing their local environment through dune restoration and shorebird protection (Opie, K, pers comm.). They are currently carrying out predator control and monitoring at six shorebird-breeding sites from Port Waikato to Waikaretu to the south as well as restoration planting within the Port Waikato dune system.

The Beachcare group, keen to find an alternative to use of artificial fertiliser assisted in establishing a planting trial on an inland bare dune to compare slow-release tablets with koi carp fertiliser (Figure 6). This included evaluating the practicality of using koi carp in pellet form compared to standard tablet form, and recording any concerns with its use by community groups such as the smell of the koi carp as well as possible interference of fertilised plants by dogs or wildlife.

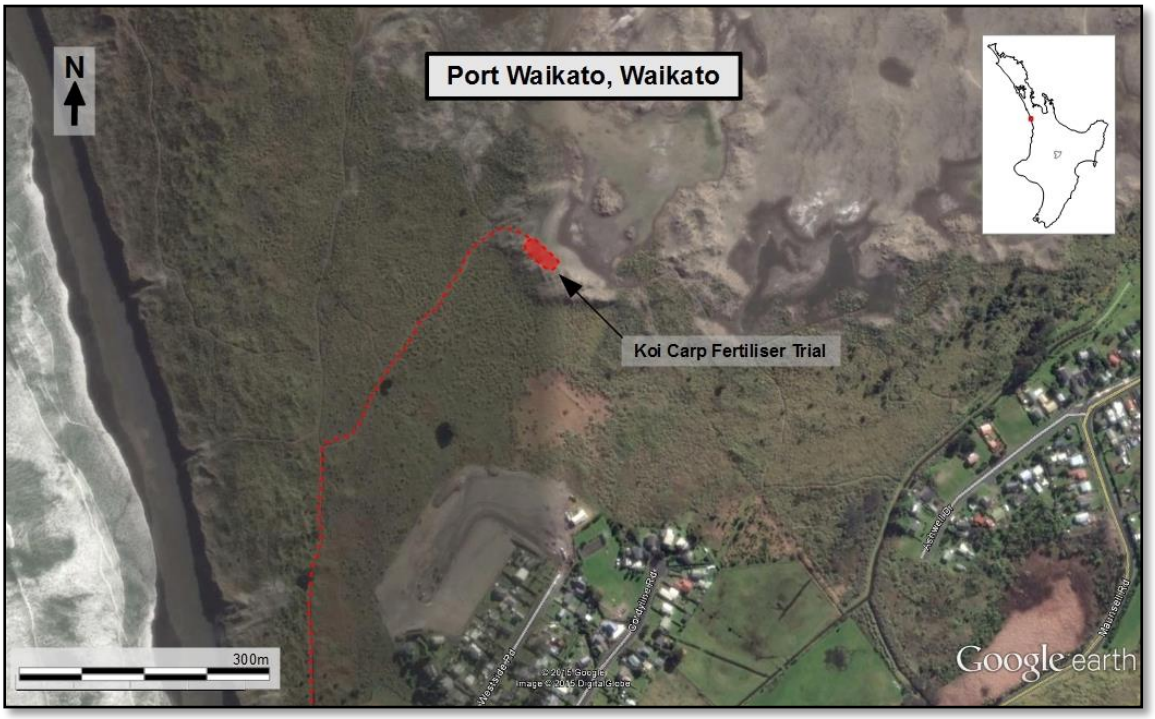


Figure 6: Location of the koi carp fertiliser planting trials at Port Waikato, west coast North Island.

Whitianga

As part of Beachcare programmes to consolidate and improve the existing dune restoration and planting programme along the eastern beaches of the Coromandel Peninsula, the Whitianga Community Beach Care Group is involved in a long term rehabilitation programme along parts of Buffalo Beach (Dahm, J, pers comm.). This involves the planting of thousands of sand binders along foredunes each year.

As part of one of these large scale community planting events, a 100 m section of recently reshaped foredune toward the southern end of Buffalo Beach was block planted with spinifex and pingao and limited numbers of selected mid-dune species to compare performance of koi carp fertiliser with fertiliser tablets (Figure 7). This was not a formal fully replicated trial.

Figure 7: **Location of the koi carp fertilizer planting trials toward the southern end of Buffalo Beach, Whitianga, eastern Coromandel Peninsula**

2 Methods

Fertiliser formulation

Koi carp was available in pelletised form and was compared with the standard fertiliser practice of using fertiliser tablets at planting. Preliminary investigation undertaken to produce koi carp fertiliser in tablet form indicated this could add substantially to production costs compared to using koi carp pressed into pellet form without binders (Bruno David, Freshwater Scientist, Waikato Regional Council, pers comm).

For these Waikato dune plantings fertiliser tablets were sourced from The Native Plant Nursery which are widely used by the Waikato Beachcare programme. The chemical analysis of both fertiliser formulations is given in Appendix 1 (koi carp) and Appendix 2 (tablets, both label and Hill Laboratories analysis). Total Nitrogen (N) for The Native Plant Nursery tablets was rated at 24% (by label similar to the Hills Laboratory analysis) and koi carp was rated at 3.2% (based on Sample C in the Hills Laboratory analysis).

Several rates of fertiliser for both koi carp and fertiliser tablets were tested for applying to each sand binder at planting. Based on weight, the amount of koi carp fertiliser required to provide an equal proportion of N was calculated for 3 rates of application - low, medium, high (Table 1). Current practice is application of a single tablet.

Table 1: **Rate for 3 levels of fertiliser to be incorporated at planting for each sand binding plant for each of the fertilisers.**

Dose rate per plant	Taupo Nursery fertiliser tablet	Koi carp pellets
Low rate	1 tablet	72g pellets
Medium rate	2 tablets	144g pellets
High rate	3 tablets	216g pellets

Three different sized containers were used to ensure consistent delivery of each of the koi carp fertiliser rates to each seedling.

Treatments and trial design

The trials at the Nukuhakari and Port Waikato sites were established using a Randomised Complete Block (RCB) design based comprising several replicate blocks. Each replicate comprised 6 fertiliser treatments with each treatment applied to a single planted plot of sand binders and two non-fertilised control plots. The treatments were:

1. Koi carp – Low rate (72g)
2. Koi carp – Medium rate (144g)
3. Koi carp – High rate (216g)
4. Slow-release fertiliser – 1 tablet
5. Slow-release fertiliser – 2 tablets
6. Slow-release fertiliser – 3 tablets
7. control – no fertiliser
8. control – no fertiliser.

The trial design was as follows:

- Each planted group to comprise a minimum of 20 plants – 10 spinifex and 10 pingao.
- 10 replicate blocks for the Nukuhakari trial and five replicates for the Port Waikato site.
- Each replicate to comprise 8 groups, one group for each fertiliser and the two control treatments, i.e. a single treatment to be applied to each group of 20 plants, plus and extra control plot for each replicate.
- Therefore the trial design for Nukuhakari was:
    - 8 treatments x 10 replicates x 20 plants/group = 1600 sand binders (800 each of spinifex and pingao) (Figure 8).
- The trial design for Port Waikato comprised half the number of replicates (Figure 9).

The trial layout was as follows:

- Plots within each replicate block were located in close proximity with a minimum of 1.5m between plot edges to reduce contamination between plots.
- Each plot of 20 sand binder seedlings was planted randomly within a 3m diameter circle which allowed an average spacing of 75cm between plants.
- A plastic waratah or bamboo was placed centrally within each of the 8 plots.
- Fertiliser treatments were assigned randomly to each replicate using a random number table.

Planting of the Port Waikato trial was undertaken on 11th October 2015 and for the Nukuhakari trial on 17-18th August 2015.

Whitianga dune planting

In collaboration with Beachcare Contractor Jim Dahm and the Whitianga Beachcare group, two replicates comprising 2 blocks each were established to compare planting of a range of foredune species with slow-release tablets vs koi carp pellets. Each block was 12m long and 8m wide with a single fertiliser applied to each block. Only the low rate of fertiliser was applied - 1 tablet per plant or 72g koi carp pellets (Figure 10)

Species planted included spinifex and pingao along the seaward 6m width of each block with a mixture of the sandbinders and wiwi (*Ficinia nodosa*) and pohuehue (*Muehlenbeckia complexa*) planted on the landward 2m zone. Block layout is shown in Figure 8. Planting was carried out on 5th September 2015.

This large scale community planting was not a formal trial and did not include non-fertilised control. Planting involved 5-600 plants each of spinifex and pingao with up to 200 each of wiwi and pohuehue. Allocation of precise numbers of plants to each planting block was not recorded but species were relatively evenly divided between the blocks. Average spacing of planting by the community was 60 cm apart for all species.

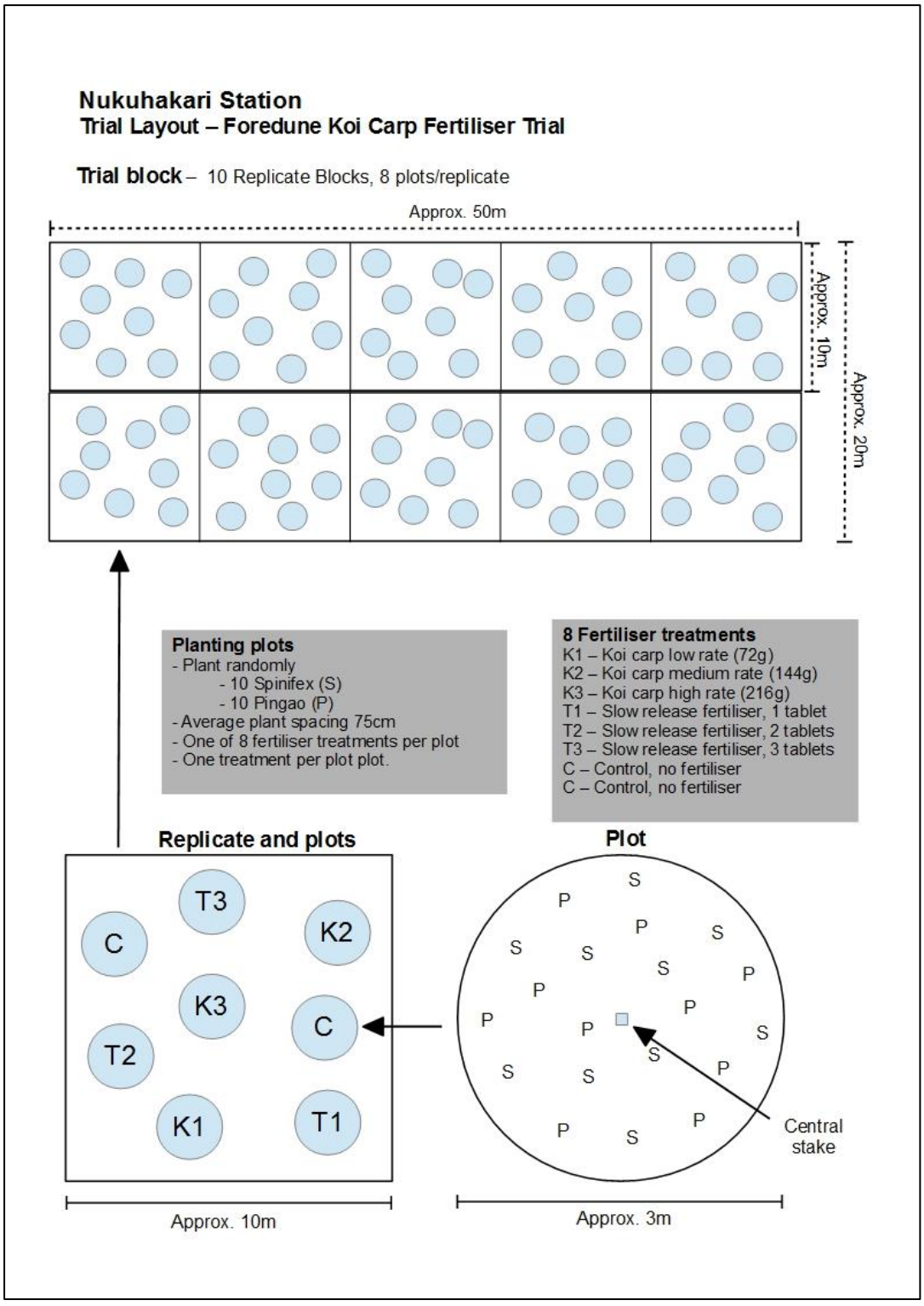


Figure 8: Diagrammatic layout of trial replicate blocks and plot design for the Nukuhakari trial site. Port Waikato site similar layout as below but only 5 replicates.

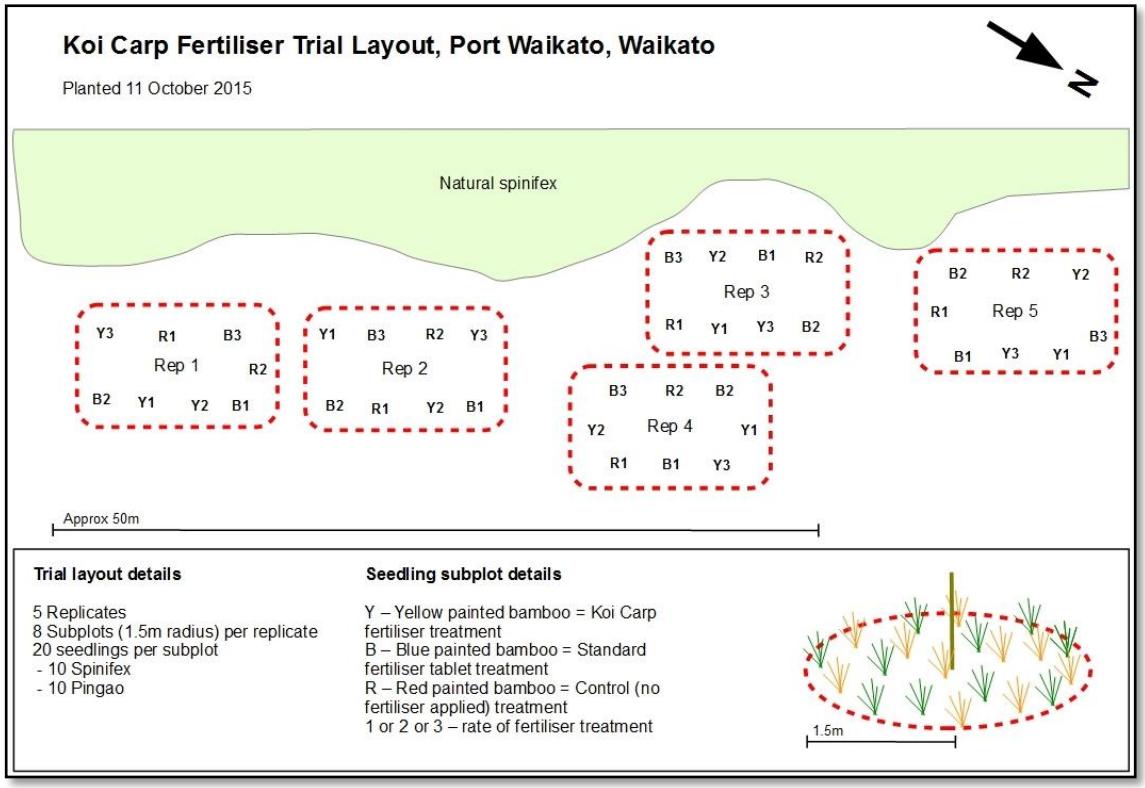


Figure 9: Diagrammatic layout of trial replicate blocks and plot design for the Port Waikato site with 5 replicates.

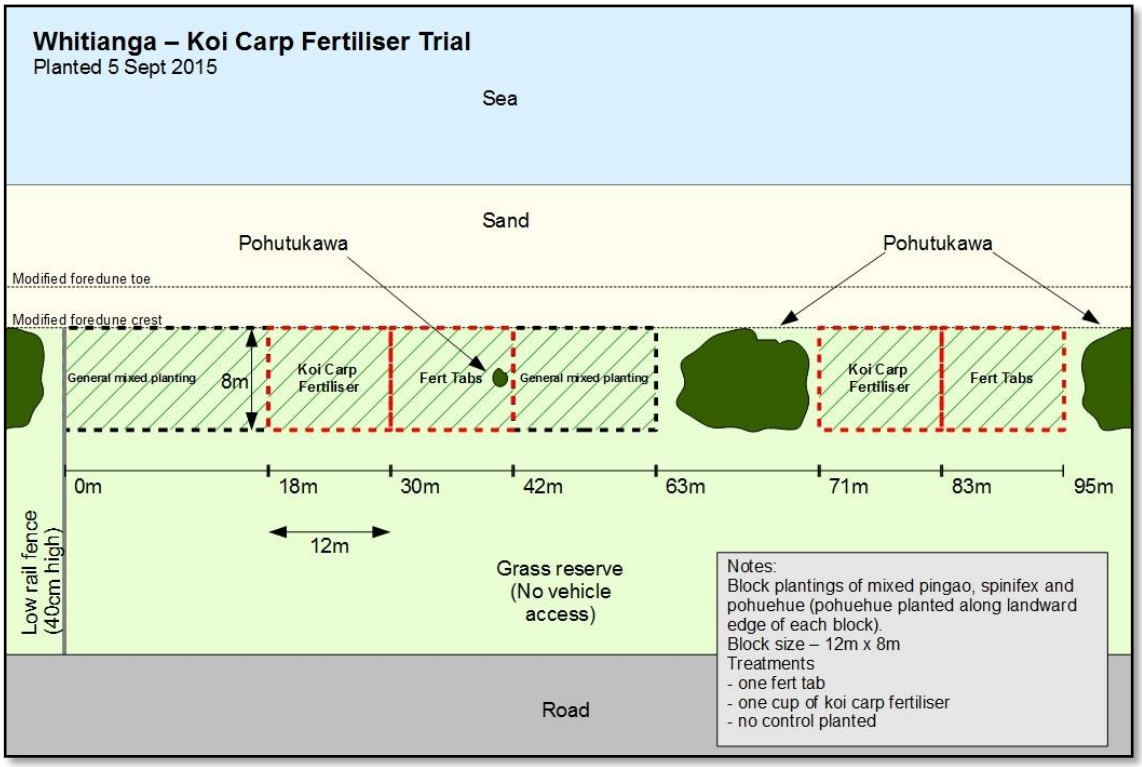


Figure 10: Diagrammatic layout of community planting blocks comparing koi and tablet fertiliser applied in a single dose at planting along Buffalo Beach, Whitianga.

Mapping, assessment and timeline

Each planting trial was mapped including GPS coordinates of each plot. Standard assessment procedures were used and included the following variables by species:

- Survival count
- Plant height
- Crown spread – length x breadth
- Plant vigour score based on subjective assessment of plant health and cover within each species:
    1. Poor
    2. Unthrifty
    3. Average
    4. Good
    5. Excellent
- Any comments on plant condition, e.g. browsing.

Trials inspections were carried out within a month of planting at most sites to determine early performance and identify any issues were affecting the trial, e.g. stock, rabbits, sand movement, etc (refer Appendix 3 for details on planting and assessment timeline for each site). Assessments were carrried at each site as follows:

- Port Waikato trial - post plant inspections monthly by west coast Waikato Beachcare Coordinator Karen Opie; full measurement at 3 months and 6 months after planting;
- Nukuhakari trial - post plant inspection 6 weeks; survival and vigour assessment 5 months after planting; full assessement at 8 months after planting.
- Whitianga site - inspection 5 months after planting; percentage cover estimates and plant cover assessment for a random sample of 30 plants per species at planting and 7 months after planting.

Data analysis

For the full assessments the following variables were analysed for data from Port Waikato and Nukuhakari trials:

- Survival
- Spread √(crown breadth x length)
- Height
- Vigour score

Analyses of variance were used to test the following experimental factors for each variable:

- Fertiliser type (control vs standard fertiliser tablets vs koi carp pellets);
- Fertiliser rate (1, 2, and 3 doses per plant); and
- Slow-release fertiliser effect for the Port Waikato site.

Separate analyses were used for each trial (Nukuhakari and Port Waikato) and species (spinifex and pingao) combination. Data was analysed for both assessments at 3 and 6 months after planting for the Port Waikato trial. As the Whitianga trial methodology differed from that used at other sites, it was not included in the analysis.

3 Results

Port Waikato and Nukuhakari trials

Performance of sand binders

The tests comparing fertiliser type (control vs tablets vs koi) are summarised in Tables 2 & 3 for both the Nukuhakari and Port Waikato trials 6-8 months after planting. These data are also presented as charts in Figures 11 & 12 showing mean survival, spread, height and vigour score for controls, koi and tablets. Values for fertilised plants are averaged across dose rates. Error bars show standard errors of means.

In most cases, fertilised plants were significantly larger than unfertilised plants with no significant difference between koi and tablet fertilisers. However in both trials, spinifex plants treated with tablets had significantly greater spread than koi-treated plants, although in both cases there was a far greater difference between fertilised plants and unfertilised plants than between the two fertiliser types (Table 2).

Table 2: Treatment means for pingao 6 months after planting the Port Waikato trial and 8 months after planting the Nukuhakari trial. Values followed by the same letter for the different treatments within a trial do not differ significantly (p=0.05)

Trial	Treatment	Survival (%)	Spread (cm)	Height (m)	Vigour score
Port Waikato	Control	21 a	16 a	32 a	1.7 a
	Koi	7 b	50 b	52 b	4.5 b
	Tablet	9 b	63 b	59 b	4.6 b
Nukuhakari	Control	29 a	52 a	49 a	3.4 a
	Koi	28 a	70 b	57 b	4.6 b
	Tablet	33 a	74 b	61 b	4.6 b

Table 3: Treatment means for spinifex 6 months after planting the Port Waikato trial and 8 months after planting the Nukuhakari trial. Values followed by the same letter for the different treatments within a trial for not differ significantly (p=0.05)

Trial	Treatment	Survival (%)	Spread (cm)	Height (m)	Vigour score
Port Waikato	Control	38 a	15 a	35 a	1.8 a
	Koi	47 b	52 b	50 b	4.8 b
	Tablet	46 b	62 c	49 b	4.9 b
Nukuhakari	Control	65 a	43 a	42 a	4.1 a
	Koi	69 a	64 b	54 b	4.9 b
	Tablet	70 a	72 c	54 b	5.0 b

There was no significant difference between fertiliser types for height or vigour for any species or site. Fertilising using either koi carp or tablet improved survival at Port Waikato for spinifex but had the reverse effect for pingao. The results of the pingao at Port Waikato are likely to have been influenced by the use of smaller less optimal stock that was available at the time when the trials were established towards the end of the planting season (Opie, K, pers. comm.).

A difference in colour was noticeable between the koi carp and tablet fertilised plants - the koi fertilised plants appeared to be more yellow compared to green for the tablet fertilised plants.

This difference in foliage colour was most apparent when adjacent plots with different fertiliser formulations were viewed. The difference in colour at an individual plant level was subtle and was not quantified. Bulk foliage samples were taken from plants across all treatments and are being analysed as arranged by Waikato Regional Council.

There were no issues reported from the Beachcare participants in use of the koi carp during planting, the smell of which resembles blood and bone, and there were no disturbance of koi fertilised plants from animals digging up the fertilised plants.

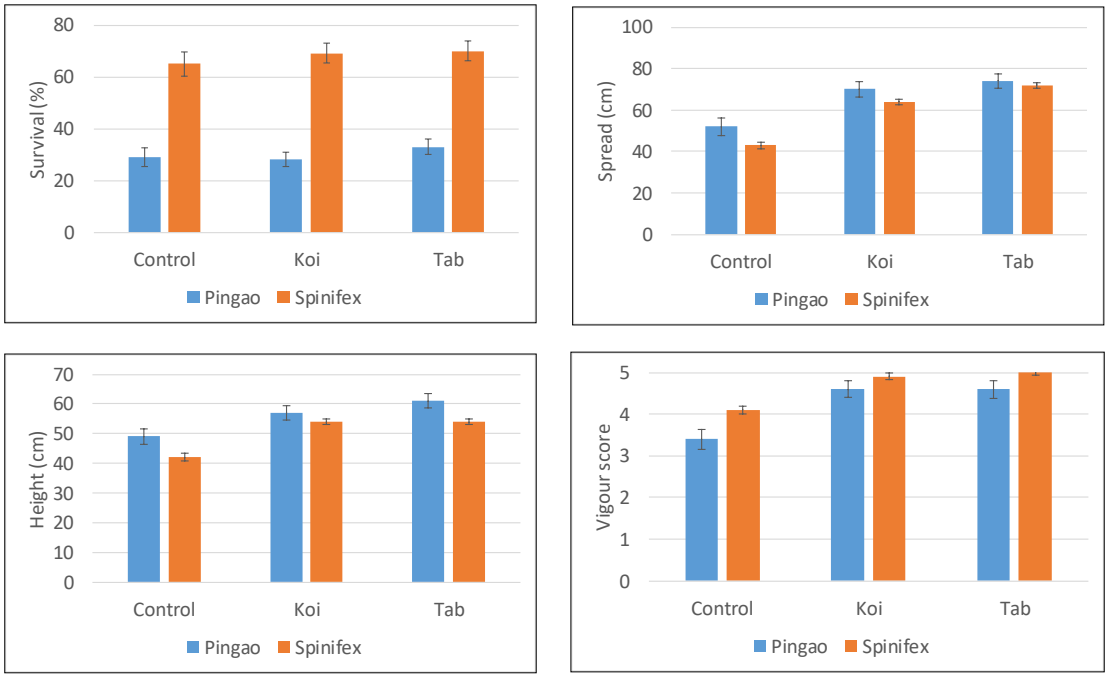


Figure 11: Performance of sand binders 8 months after planting at the Nukuhakari trial. Error bars show standard errors of means.

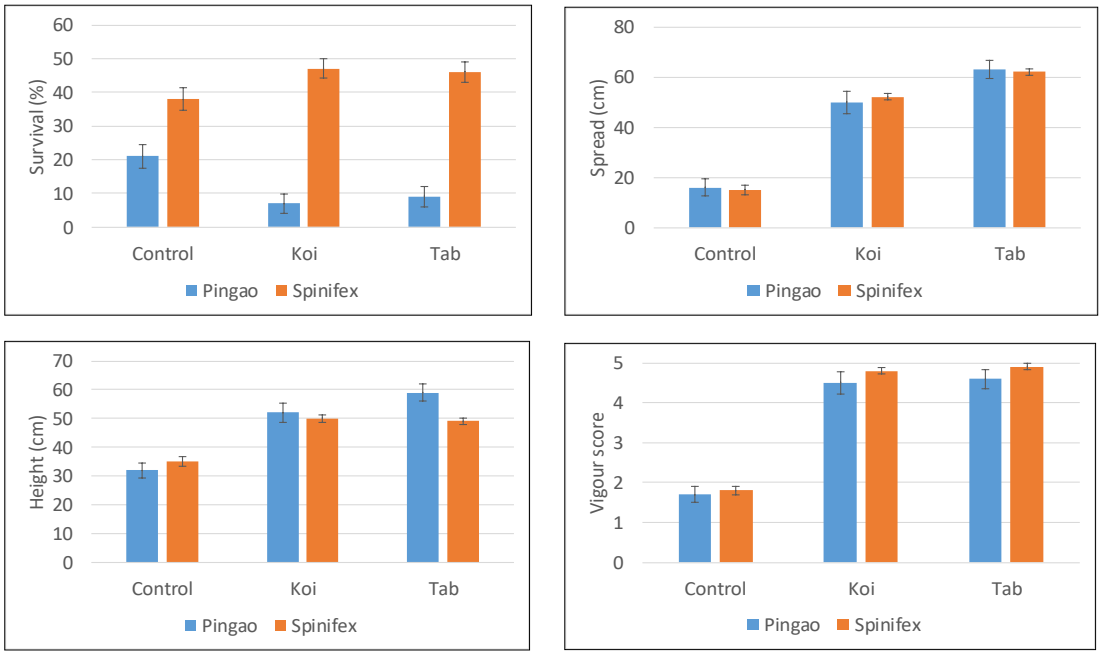


Figure 12: Performance of sand binders 6 months after planting at the Port Waikato trial. Error bars show standard error of means.

a.

b.

Figure 13a & b: Establishment of the fertiliser trials on the Nukuhakari Station dunes (a) and 5 months after planning (b)

Figure 14: Karen Opie and the Port Waikato Beachcare group planting the trial at Port Waikato

Figure 15: **Planted groups of spinifex and pingao in the Port Waikato fertiliser trial, Port Waikato. Groups are the non-fertilised control (upper left), koi fertiliser treatment (foreground), and the tablet fertiliser treatment 6 months after planting (back right). Note plots are dominated by spinifex as pingao survival was poor and likely due to poor quality of stock available for the late planting of this trial.**

Rates of fertiliser

There were no significant differences in survival or vigour between fertiliser rates (low vs medium vs high doses) for either species in either the Nukuhakari and Port Waikato trials 6-8 months after planting. While there was no significant effect of fertiliser rate for pingao in either trial, there were small though statistically significant differences in growth between the single and triple rates in some growth traits for spinifex (Table 4).

Table 4: **Effect of fertiliser rate on size of spinifex plants 6 months after planting the Port Waikato trial and 8 months after planting the Nukuhakari trial across both fertiliser formulations. Values within a column and for the different rates within a trial followed by the same letter do not differ significantly (p=0.05)**

Trial	Rate	Spread (cm)		Height (cm)	
		Koi	Tab	Koi	Tab
Nukuhakari	1	58 a	65 a	51 a	50 a
	2	63 ab	70 ab	55 a	54 ab
	3	71 b	78 b	56 a	58 b
Port Waikato	1	47 a	58 a	48 a	48 a
	2	53 ab	63 a	51 a	50 a
	3	58 b	65 a	51 a	50 a

Slow-release effect

Two assessments 3 months apart within the first 6 months of planting are compared for the Port Waikato trial for pingao (Table 5) and spinifex (Table 6). Both koi and tablet fertiliser treatments continued to show a significant increase in plant growth for both species 6 months after planting compared to non-fertilised controls where there was virtually no change in plant size from the 3 month to the 6 month measurement. However, there was a small but statistically significant increase in plant spread for spinifex between the 2 assessments fertilised with tablets compared to koi fertiliser.

Table 5: Treatment means for pingao 3 & 6 months after planting at Port Waikato trial. Values followed by the same letter for the different treatments within a trial do not differ significantly (p=0.05)

Trial	Assessment after planting	Treatment	Survival (%)	Spread (cm)	Height (m)	Vigour score
Port Waikato	4 months	Control	23 a	14 a	27 a	1.7 a
		Koi	10 b	30 b	36 a	3.7 b
		Tablet	10 b	27 b	35 a	3.3 b
Port Waikato	12 months	Control	21 a	16 a	32 a	1.7 a
		Koi	7 b	50 b	52 b	4.5 b
		Tablet	9 b	63 b	59 b	4.6 b

Table 6: Treatment means for spinifex 3 & 6 months after planting at Port Waikato trial. Values followed by the same letter for the different treatments within a trial do not differ significantly (p=0.05)

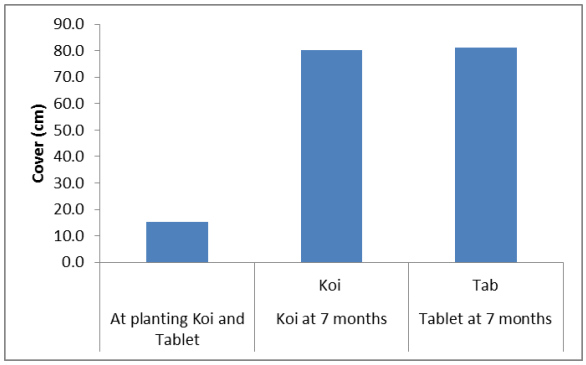
Trial	Assessment after planting	Treatment	Survival (%)	Spread (cm)	Height (m)	Vigour score
Port Waikato	4 months	Control	43 a	15 a	32 a	1.9 a
		Koi	46 a	43 b	33 a	4.6 b
		Tablet	47 a	41 b	32 a	4.2 b
Port Waikato	12 months	Control	38 a	15 a	35 a	1.8 a
		Koi	47 b	52 b	50 b	4.8 b
		Tablet	46 b	62 c	49 b	4.9 b

Whitianga community planting

Based on measurement of plant cover of a sample of plants within each block, koi and tablet fertiliser treatments have similar growth 7 months after planting with an average plant diameter of 70-80 cm (Figure 16).

Subjective assessment of overall canopy cover of fertilised blocks indicates the koi fertiliser treatment had provided substantially greater cover than the tablet treated blocks. This included the two mid-dune species wiwi and pohuehue.

a.



b.

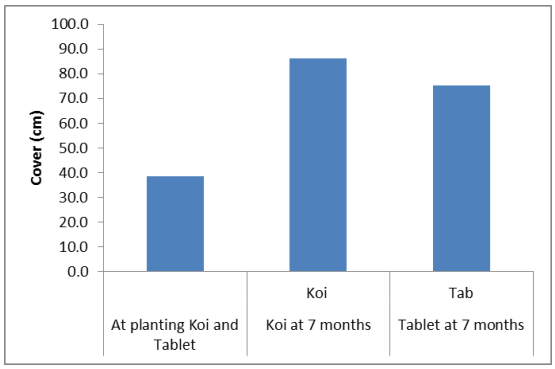


Figure 16a &b: **Average plant cover for a sample of 30 spinifex (a) and pingao (b) planted by the Whitianga Beachcare group and local community in large blocks comparing application of a single rate of koi and tab (tablet) at planting and 7 months after planting.**

a.

b.

Figure 17a & b: **Koi fertiliser treatment (a) and tablet fertiliser treatment (b) 7 months after planting, Buffalo Beach, Whitianga.**

a.

b.

Figure 18a & b: **Recently planted (a) and 7 months after planting (b) for the community planting, Buffalo Beach, Whitianga.**

4 Preliminary Conclusions

Overall, results indicate that koi carp gives a similar boost to growth of sand binders as the standard current practice of using slow-release fertiliser tablets. The substantial boost in growth by fertiliser compared to non-fertilised control plots is consistent with previous research and operational plantings over the last two decades for pingao (Bergin and Herbert 1998) and spinifex (Bergin 1999).

While there was a small increase in growth performance for spinifex with a higher rate of fertiliser, this is not likely to be sufficiently substantial to warrant increasing the standard single rate of fertiliser application in Beachcare plantings.

The smaller less than optimal quality of pingao used in the late season planting at the Port Waikato trial site combined with rabbit browse is likely to have significantly affected plant performance for this species at this site.

There may be a difference in the slow-release effect between koi carp and tablet fertiliser treatments. The small continued boost in plant spread for spinifex fertilised with tablets versus the koi fertilised plants between the 2 assessments 3 months apart in the Port Waikato trial was statistically significant. Koi carp-fertilised spinifex appeared to have foliage that was straw coloured compared to the greener foliage colour of tablet-fertilised spinifex which may indicate a supply of nutrients over a longer period from tablets compared to koi pellets. It is probable that a handful of pressed koi pellets distributed within the planting pit released nutrients quicker than specially formulated slow-release fertiliser tablets designed to release nutrients over several months.

Implications for 2016 trials

While these trials clearly indicate that koi carp fertiliser is providing a boost in growth of planted native sand binders that is similar to the standard practice of using slow-release fertiliser tablets, the trials were established relatively late in the planting season. In addition, for the Port Waikato site, the less than optimal quality of the pingao stock available and the effects of rabbit browse is likely to have compromised results.

A second series of fertiliser trials is therefore recommended for both spinifex and pingao planted on foredunes to confirm and refine results reported here. Plans are underway for further fertiliser trials at a minimum of two beaches in the Waikato region and possibly evaluating koi carp fertiliser at dune planting sites in other regions.

Monitoring methods may not be capturing differences in plant response between fertiliser treatments so further field assessment procedures to quantify plant growth will also be considered. This includes foliage analysis to determine any differences in nutrient uptake and deficiencies between fertiliser treatments and comparing these with natural populations on similar sites nearby. Photographic methods and point-sampling methods applied to grids across planted plots will also be considered and compared with existing data collection methods.

Establishment of the trials in earlier months within the planting season will allow a longer timeframe for monitoring performance before the onset of the following autumn/winter. This will also allow any differences in the slow-release effect between the koi carp and artificial tablet formulations to be monitored over a longer timeframe.

The evaluation of rates of fertiliser application indicates this could be reduced to comparing single and double doses. While the higher dose rates of koi carp pellets did give a small increase in growth, this is not necessarily boosting growth sufficiently to warrant application of the relatively large quantities of pellets required especially at the high dose rate and hence logistics of transporting and handling large volumes material. The largely observational results from the community block planting comparing only single dose rates of each fertiliser type at Whitianga also suggests that larger doses of fertiliser may not be warranted.

There is also an opportunity to include a new fertiliser treatment combination supplied by Waikato Regional Council - biochar mixed with koi carp - to compare with the original koi carp formulation, and with the standard tablets and non-fertilised controls.

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Appendix 1 – Chemical analysis of the koi carp pelletised fertiliser developed and supplied by the Waikato Regional Council.

Hill Laboratories
BETTER TESTING BETTER RESULTS

R J Hill Laboratories Limited
1 Clyde Street
Private Bag 3205
Hamilton 3240, New Zealand

Tel +64 7 858 2000
Fax +64 7 858 2001
Email mail@hill-labs.co.nz
Web www.hill-labs.co.nz

ANALYSIS REPORT

Client:	Waikato Regional Council	Lab No:	1461358	SPv1
Contact:	Mr I Buchanan	Date Registered:	11-Aug-2015	
	C/- Waikato Regional Council	Date Reported:	14-Aug-2015	
	Private Bag 3038	Quote No:	37495	
	Waikato Mail Centre	Order No:		
	HAMILTON 3240	Client Reference:	D1405 2.2	
		Submitted By:	Bruno David	

Sample Type: Fish (dry)

Sample Name:		A	B	C		
Lab Number:		1461358.1	1461358.2	1461358.3		
Total Nitrogen	g/100g as rcvd	3.8	3.9	3.2	-	-
Calcium	mg/kg as rcvd	47,000	50,000	99,000	-	-
Magnesium	mg/kg as rcvd	2,600	2,500	2,500	-	-
Potassium	mg/kg as rcvd	13,700	13,500	11,500	-	-
Sodium	mg/kg as rcvd	5,400	5,500	6,000	-	-
Phosphorus*	mg/kg as rcvd	27,000	28,000	44,000	-	-
Sulphur*	mg/kg as rcvd	5,500	5,400	3,300	-	-
Iron	mg/kg as rcvd	5,700	6,000	3,100	-	-
Boron	mg/kg as rcvd	5	5	10	-	-
Copper	mg/kg as rcvd	13.1	13.2	14.0	-	-
Manganese	mg/kg as rcvd	113	116	107	-	-
Zinc	mg/kg as rcvd	340	330	300	-	-

SUMMARY OF METHODS

The following table(s) gives a brief description of the methods used to conduct the analyses for this job. The detection limits given below are those attainable in a relatively clean matrix. Detection limits may be higher for individual samples should insufficient sample be available, or if the matrix requires that dilutions be performed during analysis.

Sample Type: Fish (dry)

Test	Method Description	Default Detection Limit	Sample No
Grind*	Grinding or crushing of nominally dry or dried sample to form ground sample fraction. Analysis performed at Hill Laboratories - Food & Bioanalytical Division, Waikato Innovation Park, Ruakura Lane, Hamilton.	-	1-3
Total Nitrogen	Dumas combustion. AOAC 992.15, 19th edition.	0.02 g/100g as rcvd	1-3
Biological Materials Digestion	Nitric and hydrochloric acid micro digestion, 85°C for 1 hour. Analysis performed at Hill Laboratories - Food & Bioanalytical Division, Waikato Innovation Park, Ruakura Lane, Hamilton.	-	1-3
Calcium	Biological materials digestion, ICP-OES.	10 mg/kg as rcvd	1-3
Magnesium	Biological materials digestion, ICP-OES.	5 mg/kg as rcvd	1-3
Potassium	Biological materials digestion, ICP-OES.	40 mg/kg as rcvd	1-3
Sodium	Biological materials digestion, ICP-OES.	50 mg/kg as rcvd	1-3
Phosphorus*	Biological materials digestion, ICP-OES.	20 mg/kg as rcvd	1-3
Sulphur*	Biological materials digestion, ICP-OES.	20 mg/kg as rcvd	1-3
Iron	Biological materials digestion, ICP-OES.	5 mg/kg as rcvd	1-3
Boron	Biological materials digestion, ICP-MS.	0.5 mg/kg as rcvd	1-3
Copper	Biological materials digestion, ICP-MS.	0.05 mg/kg as rcvd	1-3
Manganese	Biological materials digestion, ICP-MS.	0.05 mg/kg as rcvd	1-3
Zinc	Biological materials digestion, ICP-MS.	1.0 mg/kg as rcvd	1-3

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The tests reported herein have been performed in accordance with the terms of accreditation, with the exception of tests marked *, which are not accredited.

These samples were collected by yourselves (or your agent) and analysed as received at the laboratory.

Samples are held at the laboratory after reporting for a length of time depending on the preservation used and the stability of the analytes being tested. Once the storage period is completed the samples are discarded unless otherwise advised by the client.

Mark Bryant, NZCS (Chemistry)
Senior Technologist - Food & Bioanalytical Division

Appendix 2 – Chemical analysis of The Native Plant Nursery (formerly Taupo Native Plant Nursery) slow release fertiliser tablets from the label on the box of tablets used in the trials (24% total N) and the Hill Laboratories analysis (25% total N).

Appendix 2 (continued)

Hill Laboratories
BETTER TESTING BETTER RESULTS

R J Hill Laboratories Limited
1 Clyde Street
Private Bag 3205
Hamilton 3240, New Zealand

Tel +64 7 858 2000
Fax +64 7 858 2001
Email mail@hill-labs.co.nz
Web www.hill-labs.co.nz

ANALYSIS REPORT

Client:	Waikato Regional Council	**Lab No:**	1605732	SPv1
Contact:	Asaeli Tulagi	**Date Registered:**	24-Jun-2016	
	C/- Waikato Regional Council	**Date Reported:**	05-Jul-2016	
	Private Bag 3038	**Quote No:**		
	Waikato Mail Centre	**Order No:**	B1606-6	
	Hamilton 3240	**Client Reference:**		
		Submitted By:	Bruno David	

Sample Type: Miscellaneous

		Sample Name:	Terra Pro Tab 1	Taupo Tab 2			
		Lab Number:	1605732.1	1605732.2			
Individual Tests							
Organic Matter*	g/100g dry wt		58	68	-	-	-
Ash*	g/100g dry wt		42	32	-	-	-
Total Recoverable Phosphorus	mg/kg dry wt		18,000	21,000	-	-	-
Total Recoverable Potassium	mg/kg dry wt		38,000	85,000	-	-	-
Total Nitrogen*	g/100g dry wt		22	25	-	-	-
Heavy metal screen level As,Cd,Cr,Cu,Ni,Pb,Zn							
Total Recoverable Arsenic	mg/kg dry wt		5	6	-	-	-
Total Recoverable Cadmium	mg/kg dry wt		0.3	< 0.2	-	-	-
Total Recoverable Chromium	mg/kg dry wt		4	4	-	-	-
Total Recoverable Copper	mg/kg dry wt		1,180	107	-	-	-
Total Recoverable Lead	mg/kg dry wt		33	< 0.8	-	-	-
Total Recoverable Nickel	mg/kg dry wt		16	9	-	-	-
Total Recoverable Zinc	mg/kg dry wt		4,500	46	-	-	-

SUMMARY OF METHODS

The following table(s) gives a brief description of the methods used to conduct the analyses for this job. The detection limits given below are those attainable in a relatively clean matrix. Detection limits may be higher for individual samples should insufficient sample be available, or if the matrix requires that dilutions be performed during analysis.

Sample Type: Miscellaneous

Test	Method Description	Default Detection Limit	Sample No
Environmental Solids Sample Preparation	Air dried at 35°C and sieved, <2mm fraction. Used for sample preparation. May contain a residual moisture content of 2-5%.	-	1-2
Organic Matter*	Calculation: 100 - Ash (dry wt).	0.04 g/100g dry wt	1-2
Heavy metal screen level As,Cd,Cr,Cu,Ni,Pb,Zn	Dried sample, <2mm fraction. Nitric/Hydrochloric acid digestion, ICP-MS, screen level.	0.10 - 4 mg/kg dry wt	1-2
Total Recoverable digestion*	Nitric / hydrochloric acid digestion. US EPA 200.2.	-	1-2
Ash*	Ignition in muffle furnace 550°C, 6hr, gravimetric. APHA 2540 G 22nd ed. 2012.	0.04 g/100g dry wt	1-2
Total Recoverable Phosphorus	Dried sample, sieved as specified (if required). Nitric/Hydrochloric acid digestion, ICP-MS, screen level. US EPA 200.2.	40 mg/kg dry wt	1-2
Total Recoverable Potassium	Dried sample, sieved as specified (if required). Nitric/Hydrochloric acid digestion, ICP-MS, screen level. US EPA 200.2.	100 mg/kg dry wt	1-2
Total Nitrogen*	Catalytic Combustion (900°C, O2), separation, Thermal Conductivity Detector [Elementar Analyser].	0.05 g/100g dry wt	1-2

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Graham Corban MSc Tech (Hons)
Client Services Manager - Environmental

Appendix 3 – Timeline for planting inspections and assessments for each site for the koi carp fertiliser pellets and slow release fertiliser tablet trials for the three sites in the Waikato region, from planting in late winter/spring of 2015 to the latest assessments in autumn 2016.

Site	Date	Task	Participants	Approx. period after planting
Nukuhakari	26-Feb-15	Pre-plant inspection	WRC Sam, Jim, DOB, MB	
	17-18 Aug 15	Planting	WRC staff and contractors, Jim, DOB, BSB, MB, John Barran (photographer)	0
	30-Sep-15	Inspection	MB	6 weeks
	26-Jan-16	Inspection	WRC Moniqua and Karen, Jim DOB, MB	5 months
	27-Apr-16	Assessment	MB	8 months
Port Waikato	08-Sep-15	Pre-plant inspection	WRC Karen, DOB, MB	
	11-Oct-15	Planting	WRC Karen, DOB, MB, Port Waikato Beachcare group	0
	Various	Inspections	Karen and Port Waikato Beachcare group	1-3 months
	18-Jan-16	Assessment	DOB, MB, Karen	3 months
	19-Apr-16	Assessment	MB	6 months
Whitianga	05-Sep-15	Planting	Jim, DOB, MB, Whitianga Beachcare and community	0
	13-Feb-16	Inspection	Jim, DOB, MB	5 months
	12-Apr-16	Assessment	MB	7 months