WEED CONTROL OPTIONS FOR COASTAL SAND DUNES – A REVIEW

David Bergin

Before - invasion of kikuyu into a recently restored foredune, Taipa, Northland

After – effective control of exotic grasses by knapsack spraying of herbicide

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REPORT INFORMATION SHEET

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EXECUTIVE SUMMARY

Control of pest plants is a major issue for dune restoration projects. Pest plants on foredunes, particularly invasive exotic grasses, often out-compete indigenous sand binding species and reduce or prevent natural dune form and function. It is essential that restoration programmes involving the establishment and management of indigenous coastal species have effective, practical, weed control.

Plant pest control options relevant to restoration of coastal foredunes in Northland are reviewed with a focus on the sand binding seaward face dominated by indigenous sand binders. Site inspections of several representive beaches in Northland were undertaken to determine characteristics and extent of exotic weeds on foredunes where restoration initiatives are underway.

Weed control methods collated from practitioners in councils and Coast Care groups nationwide were sought via the Dune Restoration Trust of New Zealand and also from councls and published literature. This information is summarised for the control of plant pests commonly found on sand dunes.

The main method of weed control on foredunes was the use of herbicides applied by knapsack. The broad spectrum herbicide glyphosate and the grass-selective haloxyfop were the most commonly used herbicides used for control of exotic grasses and herbaceous weeds invading foredunes, especially where restoration of the dunes was underway.

Hand weeding was considered impractical other than on a small scale for non-rhizomatous species, requiring constant vigilance. Mechancial site preparation was increasingly used to reshape foredunes to a more natural slope. This method leaves the site with a higher proportion of clean sand and was considered useful for removing dense weed cover on a large scale and reducing followup weed control. The use of organic or saline sprays, mulches and biological control were not used in operational-scale foredune restoration programmes.

Information gaps were identified including the need for comprehensive guidelines for practical weed control options for community-based Coast Care groups and coastal managing agencies.

Weed control options for coastal sand dunes – a review

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Introduction

As part of an Envirolink project (Regional Council Advice No. 983-NLRC133), the Northland Regional Council required a reiview of weed control options relevant to restoration of coastal foredunes in Northland. Control of pest plants on foredunes is a major issue for dune restoration projects, particularly invasive exotic grasses out-competing indigenous sand binding species and compromising natural dune form and function.

Site inspections of a selection of representive beaches in Northland were undertaken and discussions held with selected councils and Coast Care groups both locally and nationwide during field visits and via the network of members of the Dune Restoration Trust of New Zealand (Dunes Trust) by phone and email. Information on current weed control practices used on foredunes has been collated and is of relevance to CoastCare groups and managing agencies involved in dune restoration and management.

Role of vegetation on sand dunes

Dune vegetation plays an important role in natural beach and dune dynamics and values (Dahm et al. 2005), Natural dune repair after storms is critically dependent on the presence of appropriate sand trapping vegetation on the seaward face of the dune. The key indigenous sand binding species on the seaward dune face are spinifex (*Spinifex sericeus*) and pingao (*Ficinia spiralis*). Guidelines for the establishment and management of these species are provided in Bergin and Herbert (1998) and Bergin (1999) and copies of these bulletins are widely available to councils and Coast Care groups. These guidelines, along with local council and community experience, have been used throughout Northland for restoration of coastal foredunes.

Many exotic species such as kikuyu grass (*Pennisetum clandestinum*), buffalo grass (*Stenotaphrum secundatum*), marram grass (*Ammophila arenaria*) and ice plant (*Carpobrotus edulis*) have either naturalised or been actively used to stabilise coastal dunes in many regions including the beaches of Northland. However, experience has shown that these species are not as effective as spinifex and pingao in repairing storm-damaged frontal dunes. Without a good cover of spinifex and pingao on the seaward dune face, natural dune repair between storms tends to be very limited. This can result in the next storm picking up where the last one left off, giving rise to more

serious dune erosion than would have occurred with some more natural dune recovery between the two events (Dahm et al. 2005).

With virtually all ocean beach and sand dune systems, the foredunes are an integral part of the total beach system and are subject to natural cycles of erosion and repair. These processes, sometimes referred to as “cut and fill” (Figure 1) are as follows:

i. During periods with low to moderate wave action, sand tends to move onshore and a wide high tide dry beach develops. Dry sand blown landwards is trapped by dune vegetation, which slows wind velocities near the surface causing the sand to be deposited, building up the dune over time (Figure 1i).

ii. During major storms, waves erode the beach and the frontal dune. Eroded sediments are deposited on offshore bar systems, which help to protect the beach by breaking waves offshore and thereby dissipating excess wave energy. Erosion continues until either the storm ceases or equilibrium is reached between beach profile shape and the storm waves. Immediately after storm erosion, the beach level is lower and the frontal dune is often characterised by a steep, near vertical eroded dune face (Figure 1ii).

iii. After a storm gives way to calmer weather, the sand deposited on the offshore bar gradually moves onshore restoring a high tide beach by lifting the beach level. Sand drying on the beach is blown by onshore winds against the dune scarp and a ramp of sand eventually builds up against the eroded dune face (Figure 1iii). The eroded dune face also generally collapses to a more stable slope.

iv. In extended periods without further dune erosion, the indigenous sand binding grasses on the seaward face of the dune, particularly spinifex and pingao gradually begin to extend down the eroded dune face – renewing the process of sand entrapment and gradually repairing the eroded dune face. The building of an incipient dune continues during this accretion phase to return the dune to a pre-storm profile (Figure 1iv). This natural dune repair process is relatively slow and full recovery can take years after a period of severe dune erosion.

Natural dune building and repair reinstates the protective dune following severe storm erosion. The self-repairing capacity of natural dune systems covered in indigenous sand binding plants (Figure 1iii, 1iv) is very important for the mitigation of coastal erosion.

When exotic grasses invade foredunes and dominate the indigenous sand binders, a dense sward of inappropriate vegetation develops that is ineffective in trapping wind-blown sand and building an incipient dune (Figure 2). The natural repair process is severely compromised or lost resulting in erosion of foredunes with storm events and high seas.

Wind erosion problems also occur if the cover of indigenous sand binding species on the seaward dune face is invaded by exotic grass species and can lead to severe dune damage (e.g. blowouts) and to problems with windblown sand further inland. The sand blown inland is often permanently lost from the beach system.

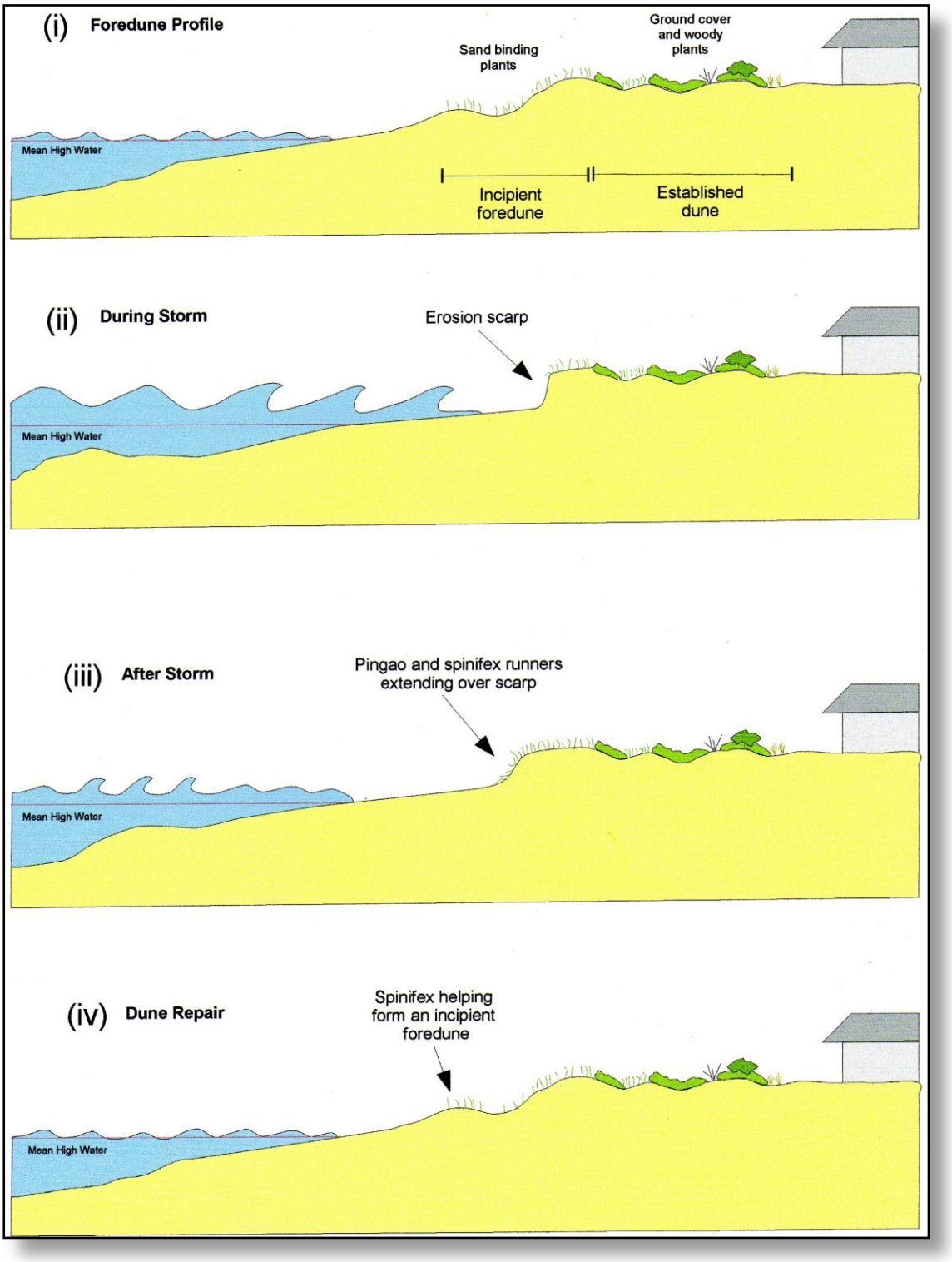

Figure 1: Natural cycles of dune erosion and recovery occur on virtually all ocean sandy beaches. The foredune profile (i) is cut back during a storm to create a steep scarp (ii). Following the storm, over the following months or longer, the indigenous sandbinders spinifex and pingao extend over the scarp to trap sand blown off the beach (iii) and an incipient dune is eventually reformed (iv). Diagram modified by Michael Bergin from Environment Waikato (2001)

The Northland Regional Council and local communities at many beaches throughout Northland have been very effective in implementing a wide range of coast care initiatives over the last decade (http://www.nrc.govt.nz/Environment/Coast/Take-action/CoastCare/). This has invoved the planting and management of key indigenous sand binding species along foredunes at many sites. However, controlling the invasion of foredunes by vigorous exotic species, particularly grasses, remains a concern at many sites and without effective control will undermine restoration efforts and reduce natural dune form and function.

Site inspections

A selection of representative beach sites where restoration of the foredunes to appropriate indigenous coastal species were inspected with Laura Shaft, Coast Care Coordinator, the Northland Regional Council, and with local Coast Care representatives. The aim was to determine the characteristics and extent of exotic weed species in and around these restoration sites where local coast care groups and agencies were actively involved in a range of dune restoration initiatives. The sites included the forshore along the reserve at Waipu Cove, the beach at the surf club at Ruakaka south of Whangarei and at Tapeka in the Bay of Islands. Two further sites were inspected in the Far North – the beaches at Tauranga Bay and Taipa.

At each site, the focus on restoration was establishing or enhancing existing colonies of the indigenous plant species mostly on the seaward face of the foredune and to a lesser extent on the semi-stable zone immediately landward. The main species planted on foredunes was spinifex with smaller numbers of pingao. Other indigenous species such as pohuehue (*Muehlenbeckia complexa*) and knobby club rush or wiwi (*Ficinia nodosa*) were either planted or naturally occurring on semi-stable sites immediately landward of the front face of the foredune and often in mixture with the indigenous sand binding plants.

At all sites, the dunes had one or more of the vigorous exotic grass species, especially kikuyu grass and buffalo grass, present either invading the foredune or on semi-stable zones immediately landward of the foredune (Figure 2). A wide range of other herbaceous weeds were also present at some sites and especially on the transition to the semi-stable landward dunes. These included the South African ice plant (*Carpobrotus edulis*), South African daisies (*Arctotis* spp.), and a host of species escaped from gardens and from the dumping of green waste.

Scope of this review

This review will focus on weed control options on foredunes where local community groups and managing agencies are actively restoring natural dune form and function often involving the reshaping and planting of the seaward face. This is primarily the indigenous sand binding zone where vigorous exotics, principally kikuyu and buffalo grass, are invading. The review will also include the semi-stable zone immediately landward that transitions into a range of other indigenous species including pohuehue and wiwi and exotic species including a wider range of grasses than just kikuyu and buffalo, the succulent South African ice plant (*Carpobrotus edulis*), a range of African daisies (e.g. *Arctotis* spp.), and many other garden escapes or herbaceous weeds from garden dumping.

The review will not cover backdunes where a wider range of natives including shrubs and trees occur and where a great diversity of exotic species including grasses, succulents, herbaceous plants and woody species are often present.

Figure 2: An example of where the exotic kikuyu grass is invading a recently restored foredune that had been densely planted with the indigenous sand binder spinifex Tapeka, Bay of Islands. Without control, the foredune will become completely dominated by exotic grasses resulting in loss of natural dune form and function thus wasting restoration efforts.

Selected information sources

From a brief exploration of the literature, there are a small number of information sources and publications related to weed control in the coastal environment. While much of this information is not directly relevant to sand dunes and weeds typically found on dunes, information on effectiveness in controlling the same or closely related target exotic species and the effect on coastal indigenous species, plus the wider implications of some treatments (such a toxicity effects on wildlife) is of general relevance to a review of weed control options on sand dunes.

A selection of these references and information sources with brief notes is provided.

Herbicide pot trials:

- No damage was noted to Cook's scurvy grass (*Lepdium oleraceum* growing on sand dunes along the Otago coast invaded by marram grass) with application of four herbicides with and without additives (penetrants, crop oil) on potted plants of kikuyu and Cook's scurvy grass (Dugdale 2000); haloxyfop is recommended option for control at a knapsack rate of 60 ml Gallant and 100ml Uptake in 10 L of water.
- Haloxyfop successfully controlled pypgrass (*Ehrharta villosa*), and invasive rhizomatous grass weed smothering dune flora at Turakina Beach, Whanganui (Harrington et al. 1998). Successive applications are required. Several other monocotyledons from dunes were unaffected by haloxyfop with

no damage to wiwi (*Ficinia nodosa*), harakeke (*Phormium tenax*) and pingao in herbicide pot trials where haloxyfop was applied at rates of 0.5 and 1.0 kg/ha with oil added.

- In pot trials, *Poa cita* (which grows on sand dunes in southern locations and closely related to the regularly planted dune plant *Poa littoralis* or hinarepe) and *Chionochloa flavicans* were severely damaged by haloxyfop, fluazifop (Fusilade) and terbuthylazine (Gardoprim), but tolerant of clopyralid and aminopyralid where herbicides were sprayed to run-off over plants (Harrington and Schmitz 2007). Herbicide tolerance of harakeke and several woody shrub species some of which occur on sand dunes were also tested.

Herbicide field trials and options:

- Control options for sea couch and salt water paspalum in estuaries (Shaw and Allen 2003). Mechanical control of saltwater paspalum is not an option as plants re-sprout from fragments of stolons and there is a high risk of spreading by machinery, livestock or by water.
- Haloxyfop has been tested for control of Mercer grass (*Paspalum distichum*), a relative of saltwater paspalum, but caused damage to non-target indigenous plants including species of *Carex*, *Crassula*, *Isolepis*, *Juncus* and *Plantago* (Champion 1998).
- Substantial information about the control of cord grass (*Spartina* spp.) in New Zealand estuaries (e.g. Shaw and Gosling 1997). Successful and selective information of *Spartina alterniflora* from part of Ohiwa harbour by the use of haloxyfop. However - this chemical can accumulate in shellfish.
- Herbicide treatments applied around indigenous plants using shields tolerate a range of formulations including mixtures of herbicides. Indigenous species found on dunes that were tested include purei (*Carex secta*) – related to various *Carex* spp on dunes (e.g. *Carex testacea*, *C. pumila*) and toetoe (*Cortaderia fulvida*), as well as whaririki (*Phomium cookianum*) and a range of woody shrub species. For more information refer to Harrington and Gregory (2009).

Saline weed control:

- Seawater has excellent potential for sustainable control of several common broadleaf weeds and sedges in seashore paspalum (*Paspalum vaginatum*) turf (Zulkaliph et al. 2011). Seashore paspalum was tolerant at salinity levels similar up to the concentration of seawater. However, additional measures would be needed to control other weed species, especially grasses.

Weed control options on foredunes

Information on current weed control practices used on sand dunes, collated from a range of source including the Dune Restoration Trust of NZ (Dunes Trust), councils, Coast Care community groups and research providers, is summarised. Detailed email responses to requests for information on current weed control practices on sand dunes from respondents are in Appendix 1.

Options for weed control on foredunes will vary depending on:

1. Whether a site is being restored to natural form and function by planting the indigenous sand binders sometimes following mechanical reshaping of the seaward face; or

2. Whether an existing foredune dominated by indigenous sand binders is being maintained to ensure any vigorous potentially invasive weed species that appear are removed.

Other factors that will influence weed control operations include which weed species are present; the scale of weed control envisaged; the resources available to undertake the work including whether it is carried out by the local Coast Care group on a voluntary basis or by contractor or agency staff; and the location of the beach and local influence such as history of management and local climate.

Based on information collated including responses from experience of practitioners in Appendix 1, there are a range of methods used for weed control on foredunes nationwide as well as options that are considered occasionally that have been tried or have the potential to be used.

Application of herbicides

- Widely used and considered a practical method by many involved in weed control on sand dunes;
- A range of herbicide formulations available but the most commonly used on foredunes are:
  - The broad-spectrum herbicide glyphosate (e.g. Roundup) which controls grasses, broadleaved herbaceous species, South African ice plant, etc…; and
  - The grass-selective herbicide haloxyfop (e.g. Gallant) which controls kikuyu, buffalo grass and most other grasses.
- The most common method of application of herbicide on foredunes is knapsack spraying; weed wipers are an option but not widely used to date;
- There are only a limited number of comparative trials on selected weed species and effect on indigenous coastal species.
- Refer to Appendix 2 for further information on use of herbicides.

Roll-back of marram grass by herbicides

- Effective use of herbicides in the Wellington region to spray back marram grass around existing spinifex on foredunes to allow natural spread of spinifex and planting of gaps.
- Haloxyfop sprayed over marram grass leading to slumping of dune faces and a new shallow foredune forming as spinifex advances.
- Broadleaf herbicide is then used to target herbaceous weeds over the foredunes and semi-stable landward dunes.

Hand weeding

- Labour intensive requiring constant vigilance but is suitable for some weeds, fragile sites or small infestations;
- Only viable at a small scale and for non-rhizomatous species to prevent invasion of exotics into a restored foredune;
- Weeds with the potential to root from fragments or germinate from any seed attached will require removal from the site.

Mechanical site preparation

- An option increasingly used in several regions for restoration of degraded foredunes is reshaping of the seaward face of the dune to a more natural low angle slope and planting with indigenous sand binders.

- Spraying of the weed cover is carried out before clearing of the vegetation and reshaping. Involves removing dense exotic vegetation cover by machines to create a 'clean' site to allow planting of natives;
- Where necessary, other material such as topsoil, clay and dumped rubbish, (a feature of many highly modified foredunes) must also be removed to return the site back to clean sand before planting with indigenous sand binders;
- These cleared and reshaped sites tend to have significantly less weed invasion than similar sites prepared by hand clearing methods;
- Follow-up weed control is still required usually involving knapsack spraying of herbicides as vigorous grasses appear.

Using tolerant plants as spray buffers

- Increasingly non-grass indigenous species such as pingao, wiwi and pohuehue are being used to provide a buffer between backdune sites and indigenous foredune grass species including spinifex on foredunes.
- This has been effective in both high use areas where exotic grasses can spread readily into adjacent restored foredunes with spinifex and in less managed sites comprising a range of backdune species including exotic gasses transition into spinifex foredunes.
- Used effectively in high-use areas along the beaches of Mount Maunganui and Papamoa.

Applications of organic or saline spray options

- There has been no specific information found on use of organic or saline sprays on sand dunes for control of weeds.
- Several formulations are available claiming to control specific weed species including those found on foredunes.
- These commercially available products include:
    - Hitman – claims to be effective in killing sprayed foliage of kikuyu (http://www.wetandforget.co.nz/hitman.htm);
    - Organic NO Weeds – Active ingredients: 150g/litre Pine Oils and 55.6g/litre Fatty Acids as a ready to use liquid (http://www.kiwicare.co.nz);
    - Further information on these products, taken from the above websites, is copied to Appendix 3.
- Salt water including concentrated saline solutions has been considered a viable alternative to herbicides:
    - Mostly anecdotal information is available – no data on comparative trials located despite interest over several years.
    - Information gleaned from informal tests indicate that saline solutions sprayed onto exotic grasses on dunes requires regular applications in ideal weather conditions to maintain restored foredunes;
    - Range of alternatives including saline and hot water, white vinegar and lemon juice promoted largely for domestic use (e.g. weeding driveways http://www.greenlivingtips.com/articles/38/1/Earth-friendly-weed-killer.html).
- Hot water or steam applications have been used for controlling kikuyu along roadside curbs in Tauranga, Bay of Plenty. No further details on its use and effectiveness collated but no evidence that its use has been sustained.
- No comparative information evaluating the effectiveness of these alternatives to herbicides and hand methods has been found. One feature appears to be that regular repeat applications of organic and saline sprays may be required.

Mulching

- Mulching or use of ground covers such as weedmat or carpet squares around planted indigenous seedlings are not suitable methods for providing weed control on foredunes.
- Natural dune form and function requires active sand movement where indigenous sand binders will thrive. Mulches will interrupt or prevent localised sand movement.
- Mulching can be useful on stable backdune zones but cost and practicality of acquiring and transporting mulches like bark, wood chip, etc.., is not practical other than on a small scale.

Combinations of weed control methods

- In some circumstances and on some sites, there will be various combinations of weed control methods;
- For instance, control of vigorous grass may require knapsack spraying to prevent invasion of grasses from adjacent parks into restored foredunes planted with spinifex and pingao but regular monitoring and hand weeding of weeds as they appear amongst established natives may be practical.

Biological Control

- Biological control is a long-term control method that reduces the vigour of infested plants involving the introduction of plant-specific insects that will control particular exotic plants. Any potential introductions are thoroughly researched and screened to ensure indigenous plants will not be affected.
- Biological control agents are being trialled by Landcare Research and a number of insects have been introduced into various regions for the control of gorse and broom. Insects are being spread as they become available and can be obtained by contacting a pest plant officer at the local regional council who will advise on their suitability for any particular infestation.
- For instance, six separate biological control agents for gorse have been released within the Waikato region. The most successful of these has been the gorse spider mite. Four broom agents have been released including the broom seed beetle, broom twig miner and broom psyllid.
- Manaaki Whenua – Landcare Research runs a national biological control programme often in collaboration with local regional councils. Refer to the Landcare Research website for more information on bio-control agents www.landcareresearch.co.nz.
- There is no known use of biological control methods for controlling invasive weeds on foredunes.

Information gaps and recommendations

This review has highlighted a number of areas where further investigation of the effectiveness of selected weed control options is required. Recommendations include:

- ***Herbicide control:***
    - Determining the tolerance of non-target key indigenous sand binding species have on a range of herbicide formulations, both selective and broad spectrum herbicides on a range of natives including grasses (e.g. spinifex) and sedges (e.g. pingao);

    - Evaluating a range of rates of application for different herbicides (e.g. including label rate, half label rate, etc) on target weed species and tolerances of oversprayed indigenous species;
    - Comparing different methods of herbicide application (e.g. knapsack sprayers vs weed wipers);
    - Timing of herbicide applications to determine whether effective weed control can be obtained in particular seasons with reduce effect on oversprayed non-target natives;
    - The relative effects of different spray regimes over size and vigour of target and non-target plant species.
- ***Non-herbicide spray options:***
    - A critical evaluation of spray option alternatives to herbicides is required;
    - This includes organic, saline and steam/hot water spray options including effectiveness in controlling weeds, practical aspects of application, cost, etc.
- ***Planting options:***
    - An evaluation of a range of scenarios to demonstrate the effectiveness of creating barriers of selected herbicide tolerant plant species (e.g. use of pingao and wiwi as a buffer between exotic grasses such as kikuyu and indigenous grasses such as spinifex and hinarepe).
- ***Guidelines:***
    - There are no comprehensive guidelines for community Coast Care groups and coastal managing agencies presenting weed control options for a range of sites;
    - Guidelines should include pros and cons of herbicide and non-herbicide options, hand and mechanical control, alternative spray options to herbicides, use of plants to shade and buffer selective herbicide use, etc.

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Appendix 1 – Cases studies – weed control information collated from members of the Dune Restoration Trust of New Zealand

As part of this review, information on current weed control practices undertaken on sand dunes was sought from practitioners via the Dune Restoration Trust of New Zealand located throughout the country. Information and opinions from selected respondents from mainly Coast Care coordinators and contractors are taken directly off emails with minor editing and formatting changes.

Coromandel Beach Care

Our approach (across many beaches where restoration has been underway, some for many years) has included hand/mechanical control, spraying and combination of spraying and earthworks. Obviously, there is no one answer and site-specific design is critical – and if you're not sure of best approach/strategy for any site, experiment with small areas to sort best approach before getting in too deep.

Briefly/simply our experience as follows:
It is always best to do a small area well rather than a large area poorly.
A strategy driven by what is best for the site is preferable to one driven by personal ideology/convictions (e.g. "it must be done by hand", "I will never use machines" or "no chemicals").

Use of hand/mechanical clearance is generally best for shrubby weed species such as coastal wattle (*Acacia sophorae*), blue pea, etc – painting stumps with weed-killer is required for more aggressive species as is follow up removal of seedlings for 1-2 years (or as required). We have also successfully eliminated small areas of ice plant with just hand control. But for most of the weeds we deal with, hand weeding/removal is just too big a job and tends to leave too much root material which rapidly comes away again.

Spraying is excellent for most things (marram grass, ice plant, kikuyu and other exotic grasses, wide range of garden plants including *Agapanthus*, etc). Stunning results can be achieved where selective spraying is practical (e.g. releasing large areas of pohuehue from kikuyu and other grasses using Gallant – usually requiring 2-3 repeat sprayings over 1-2 years for best outcomes). The best sprays and concentrations vary according to site requirements (species present, how soon afterwards you want to plant, etc). We now use professionals for most of our spraying and are prepared to pay extra for people who know the difference between weeds and natives!

However, where we have serious weed invasion and selective spraying is not practical, we have found hand/mechanical clearance and/or careful spraying are less useful. In particular, lots of problems with ongoing maintenance - and these issues can become increasingly complicated as your new plantings establish and it becomes harder to spray or mechanically remove the weeds between! There is generally too much weed material in the soil and they just keep coming back!

Nowadays, in these difficult situations we tend to use a **combination of spraying and earthworks** – wiping out the weeds with spraying, then earth-working the site back to clean sand, then planting from scratch, with follow up weed control until the

natives are well established (which can be a while depending on species, planting spacing, etc). Over the long term, this approach has given us by far the most cost-effective and best native recovery outcomes. There can be initial resistance and often adverse reaction to the mechanical clearance and so you need to do this slowly (i.e. start small) until they see how well it works. At difficult sites, this approach seriously out-performs reliance on hand clearance or spraying. We have tried alternatives as there is often resistance to use of either chemicals or earthworks, initially at many of our sites.

Where there are the same issues but over large areas, the situation is more complex again. In these situations, mechanical clearance and dense new planting of natives over large areas may not be practical – even with an effort staged over years. Careful thought and design is critical (as it is at all sites) - large areas with complex issues are just not worth taking on unless you are sure you have a proven strategy and the time, resources and community energy to see it through. Better to focus on small areas until you get the best approach sorted.

Repeat spraying over several years is one approach we have used for large areas with serious weed issues (e.g. for serious woody asparagus issues at Rings Beach - where the weed was entangled with back-dune vegetation over almost the full length of the beach!). The first spray, even when done carefully, can have a lot of collateral damage, but provided follow-up spraying is done each spring and autumn, it gradually becomes more of a spot-spraying exercise. Another strategy could be to spray/earthwork/plant the area in stages – maybe even using marram grass carefully as a temporary measure to reduce native planting requirements. Many permutations possible and the best approach will vary with site.

Caroline Bay, Timaru

Regarding weed control in dune plantings we have for the most part relied on hand weeding with a little limited herbicide control.

Caroline Bay comprises fine sand foredunes with mostly pingao, spinifex, *Euphorbia glauca* and *Carex pumila*. Other species are present in smaller numbers or at areas within the dunes where it is damper including *Carex testacea, Austrofestuca littoralis, Ficinia nodosa, Leptinella dioca* and *Apodasmia similis*.

Our biggest weed problem here has been marram grass which comprised the majority of the beach dune plantings prior to our upgrade in 2009. At that stage the whole beach was subject to re-profiling with all marram grass buried beneath the reformed dunes.

We have been fortunate that we have been able to maintain our plantings here using Taskforce Green staff and have relied heavily on hand weeding using a fork or similar to remove any odd marram grass plants which popup from time to time. This has allowed us to achieve very good results without any of the problems often encountered when herbicides are used, such as overspray onto desirable adjacent plants. It also means a lot less expense is incurred and not as much training in herbicide application etc is required by the persons undertaking this work for us. It does however require a good knowledge of which plant is which as young marram grass as plants growing amongst *Carex pumila* or spinifex are not always easy to identify so we take care to ensure that all persons can recognise the plants in this situation.

Not having to use herbicides is a plus also for any volunteers who wish to help as most people know how to use a garden fork, and weed control days can be undertaken under a much wider range of weather conditions. That said, we have used herbicide in some situations and when required this has included Roundup (glyphosate), Gallant (haloxyfop) or Buster (glusulfinate-ammonium). The Gallant is a specific grass killing herbicide while the Roundup and Buster are more broad-spectrum herbicides. Buster seems to give a greater degree of selectivity to non target plants mainly because it is more contact than systemic in its mode of action. Bang for bucks though I would have to say that Glyphoste is the most consistent product to use.

We have some newer dunes forming on the seaside of our re-profiled dunes and in some of this marram grass has re-established itself. It is our intention to progressively convert these to plantings containing species to those listed above and in these instances we will be controlling the marram grass with herbicide (Glyphosate) prior to planting. We have already started this process at a couple of locations on the Bay and are relying on the dying marram grass to hold the sand together while the new plantings that have been placed amongst it establish.
We may undertake some limited further application of herbicide at these sites as required but before the desirable plants get too big and the opportunity from overspray increases. The ideal would be to be able to ensure 100% control of the marram grass using herbicide before planting but our experience during the Bay upgrade has shown that significant sand movement occurs during wind events without any vegetation to hold it together.

Elsewhere at South Beach and Otipua Beach we have used a mix of hand weeding using our Taskforce Green, or herbicide application undertaken by contractors. At these sites lupin is also a predominant weed along with marram grass.

Dunedin and coastal Otago

Brighton Beach

A really good example of a beach returned to most of its indigenous biodiversity.
I had a look at the vegetation five years ago and apart from an initial pikao planting it was mainly marram grass, wilding pines, lupin and periwinkle. The first action was to using a scrub bar with a sharp blade to cut off the marram grass, lupin and other weeds.

Pikao (pingao), was planted mainly in the fore dunes and *Euphorbia glauca* back further. The back dune area was planted up with ngaio (*Myoporum laetum*), ti kouka (*Cordyline australis*), harakeke (*Phormium tenax*), mapou (*Myrsine australis*), *Hebe* spp., and kohuhu (*Pittosporum tenuifolium*).

Releasing was important as marram grass and yellow tree lupin (*Lupinus arboreus*) regrowth was rampant and puha grew from the planting sites as a result of the fertiliser. The herbicide used was glyphosate (Turbo) at a rate of 100ml to 10 litres and silmax penetrant at 10ml per 10ml (Turbo is reasonably inexpensive at about $120 per 20l but the penetrant is $650 per 20l but we don't use much. The penetrant is essential to get good results over a wide spectrum of weeds including young gorse and broom).

Some hand pulling was necessary to remove lupin and marram grass from the close proximity of the plantings. The glyphosate mix killed the lupin and marram grass regrowth successfully.

Grasses including marram grass were removed successfully by the overspraying with Ignite which has a similar effect to Gallant. Ignite doesn't require a penetrant as this is built into the formulation. The Ignite had no effect on the pikao or any other non grass, but it had a slight effect on *E. glauca*. Removing the grasses resulted in an influx of broad leafed weeds such as *Hieraceum*, and related weeds. Thistles also came in as a result of the open ground and at least five years of pent up lupin seedlings came up resulting in fortnightly visits to spray and pull. Ignite is fairly expensive at $2000 for 20l.

Ecological changes
Before treatment all of the weeds were present but missing was sand convolvulus (*Calystegia soldanella*), in any numbers, *Apium prostratum*, *Linum monogynum*, and *Tetragonia tetragonioides*. Once the weeds were supressed and the pikao became established the dune profile changed, with a more gentle mounding rather than scarping and as the fertility blown from the beaches moved back all of the associated dune plants responded and became more apparent. Especially obvious were the plethora of sand convolvulus, abundance of *A. prostratum* and the white flowering prominence of *Linum monogynum*.

I have just taken a breather from Brighton Beach as the amount of work to get it where it is now has been horrendous. There is no doubt that some herbicide assistance is necessary. Hand weeding will not suffice. We sometimes use the scrub cutting blade when the lupin has gotten out of hand.

One requirement of herbicide use is that systemic chemicals such as picloram (Tordon) will translocate and cause distortion and sometimes death to vascular plants.

Canterbury/Christchurch

One of main weeds here is the self-inflicted South African ice plant. The main form of potential control I think would be mechanically uplifting mats (which is how they got there in the first place).

Greater Wellington region

In response to your questions re dune restoration the work in Kapiti Coast dunelands in particular has been very successful. Over the last 3 -4 years we have embarked on large scale incipient dune restoration using the following protocol.

Firstly, on the dune toe we have sprayed marram grass around existing spinifex for 2-3 metres away from existing spinifex plants using Gallant NF, up to 5m from the MHW. Where there was no spinifex established on this toe (most of the dunes from Waimeha stream to Raumati) we sprayed the most seaward 2-3 metres of marram grass out. In these spinifex free areas we then planted 2 rows of spinifex at 1 m centres approx 1-2m above MHW along the toes of the dunes. As this 'blanking' has proceeded down the coast we have continued with our 'rolling front' where 2-3 metres of marram grass have been sprayed out around all existing and planted spinifex. The planted and established spinifex has spread back each year as the marram grass decays until in places we have now 10 metres of spinifex dunes. In the

areas planted 2-3 years ago we also have dune growth of the spinifex profile 2-5 metres further out to sea than when marram grass persisted.

What tends to happen as the marram grass behind the spinifex dies is that the top of the marram grass dune faces slumps and the new shallower angle is quickly reclaimed by advancing spinifex. In the Waitohu dunes this rollback has reached the stage where the *Fiscinia* now grades into the spinifex and marram grass is now sparse and no longer dominant.

With this method we now have an unbroken development of spinifex established for over 5km. A very cheap and effective establishment of foredune process occurs, within 18 months the swell of the spinifex dune profile is very evident, after 2.5 years it is very pronounced.

In addition to this marram grass (and exotic grass e.g. buffalo, kikuyu) spray sweep with gallant over this 5-10 m incipient dune we have run over the same area with a broadleaf spray targeting yellow tree lupin, *Senecio elegans*, exotic dandelion (*Taraxacum officinale*), iceplant, etc. This has allowed the spinifex, *Lachnogrostis billardierei* and any pingao to really take off. The entire cost of this grass and broadleaf 'rollback' each year is approximately %5000 – cheap as chips in terms of restoration.

As well as the incipient dune we have also been looking at large scale weed suppression across the rest of the foredunes/ backdunes. Under various projects this year over 10 hectares in Kapiti will be largely cleared of woody weeds; boxthorn (*Lycium feocissimum*), boneseed (*Chrysanthemoides monilifera*), coastal wattle, cherry (*Prunus* spp.), pine (*Pinus* spp.), banksias (*Banksia integrifolia*), acacias (*Acacia* spp.) etc etc. When budget has allowed in the past we have nailed large patches of exotic climbers/ groundcovers at Paraparaumu Dunes in particular cape ivy (*Senecio angulatus*), blackberry (*Rubus fruticosus*), pampas (*Cortaderia* spp.). The result has been a shift in the balance of the ecosystem to a more native dominant one. We will augment this over this large site by planting 'nodes' of 200-300 plants from which to create a seed source to spread out from.

This month we finally blanked the last gaps north of Raumati to Waimeha and have extended this line 1km north towards Peka Peka. We will continue the spray rollback for the spinifex this year and until we reach the Waitohu stage.

Appendix 2 – Use of herbicides of foredunes

Summarised from Bergin and Silvester (2011).

Most common herbicides

By far the most common method of weed control on foredunes is the use of herbicides. Two herbicides used the most on sand dunes are glyphosate and haloxyfop. Both of these herbicides are applied to weed foliage where the absorbed chemical is translocated to other parts of targeted plants including the root system, i.e. they have some systemic capacity. General information on these two herbicides including weeds controlled and use of each herbicide, rate for application using a knapsack, plus the care required in their use is presented in Table 1 from several sources including Davis and Meurk (2001), Ledgard and Henley (2009) and information from Regional Council websites (e.g., http://www.arc.govt.nz/environment/biosecurity/pest-plants/herbicides).

Herbicides should be selected according to the grass and weed cover to be controlled and always following the manufacturer's instructions for use and at the label rate. All herbicides have their limitations both for weeds controlled and for their effect on the environment. All users must ensure they obtain all the necessary information on the appropriateness of herbicides they intend to use, including local council restrictions, risks to the environment and safety requirements.

When to spray

Depending on the grass sward and the herbicide chemical used, spraying should be carried out at least a month before planting (Ledgard and Henley 2009). This will allow time for the herbicide to be taken up by the vegetation and for sprayed areas to show up. In cooler areas, some herbicides may take several weeks to be visible and marker dyes may be needed to aid detection of spots (refer to later section).

As most herbicide formulations operate by uptake of chemical through green leaves and stems, it is best to spray herbicide when there is a high level of actively growing foliage present in the crown. Uptake of chemical by recently cut vegetation, by plants that have frosted or salt-burnt foliage or by plants that are dormant is likely to be less effective than healthy growing plants with plenty of leaf surface area. In addition, for improved foliar uptake, herbicides are likely to be more effective if sprayed early in the day, but after dew on leaves has dried.

Additives for herbicides

Marker dyes

A marker dye can be added to the herbicide to clearly indicate the areas sprayed and to reduce missing areas or over-spraying already treated sites ("skips or overlaps"). They are a non-toxic coloured indicator for use in many agricultural applications including mixing with herbicide spray operations. Marker dyes come in several colours. Red and blue show up particularly well on grass sites. Areas sprayed with dyed herbicide remain visible for 2-3 week after spraying, thereby allowing identification of sprayed spots for planting before grass shows signs of dying. Marker dye also aids in detecting any spray drift.

Marker dye is particularly useful in spot-spraying operations where the time between site herbicide application and planting is reduced, where it is difficult to distinguish dead or dying grass, or where the centre of sprayed spots in rank sites with dead tops are difficult to find.

Table 1: The two herbicides most commonly used on sand dunes for control of grass and herbaceous weeds (based on information from several sources).

Herbicide - active ingredient (Selected products*)	**Mode of action**	**Weeds controlled**	**Use for preparing grass sites for planting natives**	**Rate for knapsack application (based on 10 L tank)**	**Warnings/comments**
Glyphosate (Roundup® G2, Renew, Glyphosate 360, Trounce®, Zero, Touchdown)	Absorbed through foliage and translocated to all parts of plant including roots	Non-selective; controls most annual and perennial grasses and broadleaved weeds; useful for vines and some shrubs	Used as a pre-planting or a release spray; can be short term control; useful for stem/stump treatment	100 ml/10 L water	Low toxicity; non-volatile; spray drift must not contact foliage or green bark of desirable trees; non residual – site can be planted immediately; some formulations permissible over water but need to check local Regional Council rules for any restrictions
Haloxyfop (Gallant® NF, Ignite)	Emulsifiable concentrate; foliar active with minimal soil activity;	Selectively controls grasses; can damage other monocots (cabbage trees, flax, rushes, etc…); doesn't kill broadleaf plants, ferns, etc	Can be mixed with Versatil, Gardoprim or Simazine for controlling clovers and broadleaved weeds	12.5-60 ml/10 L water depending on grass species (refer manufacturers specifications)	Harmful substance; low volatility; flush all equipment several times immediately after use; short soil residue; rainfast one hour after application

* Note – List of trade/product names is not necessarily complete or endorsing any particular brand, supplier or manufacturer. Consult suppliers and/or manufacturers for the range of products that are available including their appropriate specifications and use. Information on herbicide use is readily accessed from websites and Fact Sheets from manufacturers and local councils.

Manufacturers provide instructions on the use of marker dyes for a wide range of applications. The dosing rate depends on the type of terrain, vegetation cover being treated; intensity of colour required and the period the marker is to remain visible. Higher dosing rates will give a darker spray pattern. A suggested starting rate is 3-5ml/10L. It is recommended that the dye is added half way during filling of the tank to allow adequate mixing. Care in its use is advisable to reduce colouring of equipment, clothing and skin.

Wetting agents

The effective spread and uptake of any spray is greatly enhanced by the addition of a wetting agents (also known as a surfactants or penetrants). Wetting agents are essentially detergents that break down the surface tension of water and allow water-based herbicides to more evenly wet a surface and assist in penetration of the leaf. Advantages of different formulations of wetting agents are usually listed on manufacturers' labels and in any Fact Sheets, but in general include improving the:

- Ability of herbicides to penetrate leaf cuticle or stomata, thereby raising effectiveness and lowering cost though lower application rates or need for re-spraying; and
- Rapid uptake of herbicide, thereby reducing rainfast periods significantly so that spray operations may be carried out more successful before any pending rain.

Wetting agents should always be added last to the spray mix to prevent foaming. Rates are normally 0.1% or 1 part wetting agent per 1000 L of spray mix, which equates to approximately 10 ml of wetting agent per 10 L of spray mix. Products are available at agricultural supply stores and some garden centres include Pulse®, Boost®, Freeway, Dewdrop and Kiwi Buddy.

Care with herbicides

Herbicides can be hazardous and require careful handling and use. Before purchasing or using any herbicide, it is important to read carefully the product labels and Safety Data Sheets provided by suppliers. Many local authority websites also offer advice on choice and use of herbicides. There are various recommendations when using herbicides listed by Porteus (1993) and others including:

- Follow manufacturer's recommendations carefully for determining the correct chemical, handling instructions and application methods and quantities of herbicide.
- Use protective clothing as needed.
- Determine the most appropriate equipment including spray nozzle.
- Become familiar with safety warnings, precautions and first aid measures.
- Following recommended precautions to avoid spray drift to neighbouring properties and contaminating waterways.
- Spray only in calm conditions when rain is not expected for several hours.
- Prevent non-target species from being sprayed (usually as a result of spray drift).

Appendix 3 – Information on an organic weed killer

Hitman

(downloaded from http://www.wetandforget.co.nz/hitman.htm)

Now - buy Hitman as a 4L Concentrate or as a 4L 'Ready To Use'
Hitman Organic Weed Killer is an incredibly fast, non selective weed killer, derived from plant fatty acids. It is organic and totally natural.
Be careful not to overspray.
Protect your *wanted* plants.

How Does Hitman Work?

On contact **HITMAN** Organic Weed Killer rapidly breaks down the cellwall, dehydrating the weed and causing rapid wilting – in most cases within 2 hours on hot sunny days. **HITMAN** Organic Weed Killer leaves no residue in the soil and can safely be used on weeds in vegetable plots or flower gardens to eradicate them.

Hitman deals to the same weeds that glyphosates kill such as broad leaf weeds, thistles, grasses etc
Great for weeds coming through cobblestones or paving. You must ensure a good coverage of all the foliage to get best results. If new shoots happen to come through they may need to hit it a second time. Application is best at the hottest time of the day to accelerate dehydration of the weeds.

- **Agapanthus** – No
- **Bamboo** – No
- **Barley Grass** – No as this is like a wheat
- **Blackberry/Blueberry** - No. They can be prickly vines and a major weed on pastures. Hitman doesn't do those huge perennial weeds
- **Broom** – No
- **Buttercup/creeping buttercup** - Repeat sprays will do quite a bit of damage to this plant.
- **Clover Weed** - Yes - It'll burn off but, it won't kill it permanently. This is a serious weed
- **Convolvulus** - No. It's another tough perennial vine. Leaves may burn off but it has great strength and resources - and will grow back
- **Cooch** - Couch is too vigorous a grass to simply control by burning off with Hitman. Even with systemic products like Roundup it's very hard work, requiring many applications to get on top of it!
- **Dock** – a perennial weed. Hitman will have a reasonable effect on dock as long as it receives two or three repeat sprays. It's a matter of exhausting the regeneration process as they can refurbish their leaves only a limited number of times
- **Ginger plant** – will knock it back but it's unlikely to affect the bulbous root
- **Gorse** – Not unless it's at its very young stage
- **Hydrocotyl** - Yes
- **Ivy** - No. No miracle cure spray that would knock it in one go. The best thing to do is cut it off just above ground level and smear the stumps (both the ones in the ground and the ones towards the air!) with "woody weed killer" or "ban vine"; which are both available from plant stores. You may need to do that a few times to get a reasonable amount of control.
- **Jasmine** – No. It is a tough beast that simply replaces the burned foliage with new shoots and leaves. Another problem with those long, tough vines is that you often can't spray it all as a lot of the leaves are totally hidden deep inside the thicket
- **Kikuya** – yes. It will burn it off where you want it to stop but it will come back, so you will need persistent spraying. Use Hitman as a boundary spray
- **Ladder Fern** – It burns the foliage but the bulbs will sprout. Needs persistent sprays
- **Liverwort** – excellent on this
- **Onion weed** – No. Will burn it but there will be regrowth. Difficult weed to control!
- **Oxalis** - Yes - It'll burn off but, it won't kill it permanently. This is a serious weed
- **Paspallum** – yes
- **Penny Royal** - No
- **Ragwort** – another perennial weed. Hitman will have a reasonable effect on ragwort as long as it receives two or three repeat sprays. It's a matter of exhausting the regeneration process as they can refurbish their leaves only a limited number of times
- **Wandering Willy** – No. It's a soft-leaved, dark green creeper that lives in dark, damp places and it would be difficult to capture all the leaves

Organic No Weeds

(downloaded from http://kiwicare.co.nz/index.cfm/1,236,0,0,html/Organic-NO-Weeds?gclid=CJypncn41qkCFQvKKgodW2UWMA)

ORGANIC NO WEEDS

Summary

Watch your weeds wilt and die within hours with new Organic NO Weeds. Organic NO Weeds is certified organic by BioGro® and uses a combination of natural weed killer technologies to achieve spectacular results. With a combination of both natural pine oils and plant fatty acids formulated in the product to strip the waxy cuticles and plant cell walls from weeds, the product works spectacularly fast, particularly on warm dry days.

Organic NO Weeds is a non-selective foliar herbicide for use around the home and garden. Organic NO Weeds causes rapid dehydration, wilting and death. It quickly and effectively controls a wide range of grass weeds, broadleaf weeds, clovers and mosses. Organic NO Weeds is non-systemic and is inactive in the soil.

This product is ideal for use on emerging weeds and mosses in your flower beds and paths without using non-natural chemical herbicides.

Directions

This product is ready to use. Read the label completely first. Shake well before applying. Adjust nozzle into SPRAY position and spray entire weed until thoroughly wet. Turn nozzle to OFF position after use.

For best results spray when plants are actively growing. Spray in still dry conditions. Thoroughly wet upper and lower surfaces of weed leaves if possible. Do not wash Organic NO Weeds off foliage. Rainfall within 2 hours may reduce effectiveness. Visual effects of treatment will become apparent after 3-10 hours in warm dry conditions. Perennial and well established weeds may need further applications at 3-5 day intervals for full control. Avoid spray drift onto foliage of desirable plants as damage may occur. Hose any overspray from desirable plants immediately. Wait until treated weeds have died off before mowing or cultivating. Organic NO Weeds may be unsuitable for some coloured paving stones. Test on a sample area before full application. Avoid spraying aluminium and rubber. Do not contaminate waterways or fish ponds.

Active ingredients: 150g/litre Pine Oils and 55.6g/litre Fatty Acids as a ready to use liquid.