Cuscuta campestris

Host themes and preferences.

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āta mātai, mātai whetū

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Contents

Executive Summary

- *Cuscuta campestris* is an Unwanted Organism in New Zealand (NZ) (MPI, 2024) and listed in the Waikato Regional Pest Management Plan 2021-2031 for Progressive Containment. It is known only to be present in five wild populations in the Waikato (*pers. comm*. K Bodmin[1], 2022), and was recently found at a sixth site in Hauraki in 2024 (*pers. comm K Bodmin, 2024*). Two of these sites, Whangamarino Wetland and Kopuatai Wetland, are internationally important RAMSAR wetland sites.

- *Cuscuta campestris* has the potential for further entry into NZ through contaminated seed lots due to the morphological similarities between *C. campestris* and *Trifolium repens* – a common host of *C. campestris* overseas. MPI has had one or two seed contamination reports annually since 2022 (*pers. comm K Bodmin,2024*).

- *Cuscuta campestris* is a parasitic plant which smothers its hosts. It can deteriorate high value conservation landscapes and contribute to significant production losses in crops. It is a known weed of 25 crops in 55 countries (Kogan and Lanini, 2005). Its impacts relate to its rapid growth and smothering habit, impeding plant growth in riparian and productive landscapes. It also is toxic to stock when consumed, leading to stock ill thrift or death (Abutarbush, 2013).

- The overall objective of this research project was to determine the host range and threat of *Cuscuta campestris* to NZ ecosystems through glasshouse and laboratory investigations, identifying host themes, and profiles and preferences where possible. This is to support decisions with its progressive containment and elucidate its threat to culturally significant NZ native plants (untested hosts).

- This report is the second and final milestone in investigating *C. campestris* host plants. A score system and visual assessment categorises *C. campestris* hosts into primary, secondary, vegetative hosts or non-hosts. Host themes considered host taxonomic family, growth habit, whether hosts were native or exotic, or significant to agriculture. Potential threats by *C. campestris* to rongoā were also considered. Additionally, we also specifically reviewed whether *C. campestris* can host on young, green *Bolboschoenus fluviatilis* seedlings, an important wetland species, as previous work did not identify mature, established *B. fluviatilis,* as a host.

- Results in brief found there are few non-hosts of *C. campestris* but there is variation in host susceptibility and host preference which relates to this pest plant's impact. Attributes of non-hosts were usually monocots (although not exclusively) or plants with physical barriers to parasitism due to hard lignified stems or heavy fibrous sheaths preventing *C. campestris* haustoria entering the vascular bundles. An unexpected exception was *Cichorium intybus* (chicory) as this non-host did not possess any of these attributes and belongs to a preferred host taxonomic family (Asteraceae), but it did not host *C. campestris* from either pre-germinated seed or from fragments in our trial. Chicory has been identified to possess numerous active phytochemicals (Rees and Harborne, 1985 and Qadir et al, 2022) and further work to determine the mechanism Chicory resist hosting by *C. campestris* would be of interest.

[1] Kerry Bodmin (Freshwater Biosecurity Coordinator, Department of Conservation)

- Host testing of New Zealand natives, commonly used in riparian planting, determined *C. campestris* did not host on *Leptospermum scoparium* (manuka), *Cordyline australis* (cabbage tree) and *Phormium tenax* (flax). These natives should be preferably used, along with known monocot non-hosts such as *Carex* spp., in riparian planting where *C. campestris* is known to be present. *Lolium perenne* (perennial rye grass), *Cichorium intybus* and *Zea mays* (maize) were also classified as non-host and may be an option, in suited productive land, as a buffer zone or used as a rotation break crop. Further work on *C. campestris* seed and fragment survival in maize silage and toxicity limits in maize silage however should be known before this maize recommendation could be practically implemented on-farm.

- Young seedlings of *Bolboschoenus fluviatilis* were considered non hosts as *C. campestris* stems growing on *B. fluviatilis* were weak and although it did not flower (incomplete lifecycle) on one occasion haustoria did penetrate the host plant. The regeneration capabilities are therefore not impacted by *C. campestris* unless it can find an alternate host nearby. A consistent exotic dicot weed programme would therefore reduce *C. campestris* impact on this important wetland species.

- Of the plant hosts tested in this study considered of significance to Māori rongoā, 60% hosted *C. campestris*. This is not unexpected due to *C. campestris* preference for dicot species over monocots and tropism towards hosts with high chlorophyll content, which are likely a more energetically suitable host. This does highlight a risk to rongoā if these preference cues (green, dicots) are also meet. *C. campestris* showed a very strong preference for *Piper excelsum* (kawakawa), deemed from our investigation as a primary host.

- This NZ specific data can inform weed management plans and riparian planting choices at these wild population sites. We learnt *C. campestris* dispersal could be aided by falling fragments (e.g. human or waterfowl dispersal) as well as from germinated seed but preventing flowering is still the main aim in containing and controlling further spread of this pest plant.

- Going forward, it would be useful to capture this pest plant's impacts and dispersal in a changing climate to determine geographic risk areas and learn more about non-host resistance mechanisms which could be used to contain *C. campestris* wild populations and prepare for future wild population incursions. Non-chemical weed management practices such as shallow cultivation or mulching to disrupt *C. campestris* germination; temperature effects on *C. campestris* seed shed and how that impacts chemical control timing; and the effect of light spectrum cue differences from hosts leaves or shading in affecting a host's resistance to parasitism by *C. campestris*.

1. Background

1.1 Background

Cuscuta campestris is an annual parasitic plant. It has a wide distribution across temperate, sub-tropical and tropical regions of the world, and is a known weed of 25 crops in 55 countries (Kogan and Lanini, 2005). It is an Unwanted Organism in New Zealand (NZ) (MPI, 2024) but is present in five wild populations in the Waikato, with a sixth site found in Hauraki in 2024. Of the six wetland sites, Whangamarino and Kopuatai Wetlands are two internationally significant RAMSAR sites. It is also listed by Waikato Regional Council as a Progressive Containment plant in their 2022-2032 Pest Management Plan.

Although in isolated locations presently, this pest plant has the potential for further entry into NZ through contaminated seed lots. This pest plant's bright colour and spaghetti like growth habit means it occasionally gets cited on i-Naturalist or community threads hosting on vegetable seedlings and was once found on eucalyptus tree seedlings leading to the Ministry for Primary Industries (MPI) intervention. *C. campestris* seed is also known to survive post animal ingestion and could be dispersed from containment sites by fauna (Haidar et al, 2010). From this research, stem fragments also provide a viable dispersal mechanism.

1.1.1 Impacts

Infestation of *C. campestris* will smoother flora resulting in both production and amenity losses. The most common crops damaged by *Cuscuta* spp are potatoes, sugar beet, onion, clover and carrot. Losses by the genus *Cuscuta* are wide ranging but yield reductions over 50% is not uncommon (Mishra, 2009) as herbicides damage both C. campestris and its host, often crops just need to be ploughed into the soil. Yield losses by C. campestris in a New Zealand crop environment is not known. *C. campestris* is toxic to stock. Hay containing 50-60% *C. campestris* caused diarrhoea, vomiting and palpitation in horses (Movsesyan and Azaryan, 1974), its parasitism may also transmit viruses to crops (Adhikary and Patra, 2023), and is a threat to wetlands as it smothers wetland bird habitats and reduces wetland food sources. It is of particular concern as it has been found at one of New Zealand's high value wetlands, Whangamarino Wetland (RAMSAR site), home to endangered Matuku or Australasian bittern. Matuku are critically threatened with fewer than 1,000 birds nationally and are a taonga to Māori, appearing in their legends and the bird's feather is used for ceremonial decorations.

Cuscuta attached to herbicide resistant plants have also been found to exhibit herbicide resistance (since *Cuscuta* is in a sense just a stem on a host) indicating an evolving impact. *C. campestris* has shown herbicide resistance to ALS herbicides (Chlorsulfuron and Sulfometuron methyl) in Israel in 1994 (Rubin, 1995).

1.1.2 Control

Low transpiration rates of *Cuscuta* impede activity of soil applied herbicides and post attachment control often requires killing or injury to the host. Therefore, effective herbicide control options are those that kill or severely injure the host species thereby killing or starving *Cuscuta* plants. Chemical control options used in Australia are glyphosate or triclopyr + picloram mix (https://www.agric.wa.gov.au/herbicides/golden-dodder-control?).

1.1.3 Biology

Cuscuta campestris seed may survive in the field up to 10 years but a significant proportion (50%) of seed viability loss will occur in the first three years (Hackell and James, 2023). Progressive containment is therefore achievable if flowering and seed rain can be prevented.

C. campestris is a parasitic plant without leaves or roots living entirely above ground but it can support itself for up to 2-3 weeks without a host from seed reserves (Benvenuti *et al*, 2005). It can also self-parasitise to extend its ability, in both space and time, in finding a host (Dawson *et al*, 1994). Rootless seedlings of *C. campestris* generally reach hosts within 2 to 6 cm in distance (Benvenuti *et al*, 2004). *C. campestris* uses chemical cues to detect volatile substances from host plants (Runyon et al.2006) and red and far-red light cues to promote circumnutation (coiling) of a shoot before host contact. Shading produces more far-red light (plants reflect far-red light from leaves) and reduces the velocity of circumnutation (Yokoyama, 2023).

Parasitism is through the development of haustorium where it attaches to the host plant and gains access to the host's vascular bundle system where it absorbs host resources (Dorr, 1987). *C. campestris, like other Cuscuta* spp. is an obligate parasitic plant and requires a host to complete its life cycle (Westwood, 2010).

1.2 Previous Cuscuta reports

1.2.1 2022 Report

In 2022, the AgResearch report (#12167), "***Cuscuta campestris* seedbank evaluation from Lake Whangape and Whangamarino Wetland, Waikato region, NZ**" identified *C. campestris* host plants replicated in Table 1. All these plants are present at the Department of Conservation Te Papa Atawhai (DOC) managed Waikato wetland sites where *C. campestris* wild populations have been identified.

Table 1: Host plants of* Cuscuta campestris *identified in 2022 and 2023 reports.

Exotic weed hosts	**Native hosts**	**Exotic grasses/ sedges host**	**Agricultural weed host**
Alternanthera philoxeroides (Alligator weed)	*Persicaria decipiens* (Swamp willow weed)	*Cyperus eragrostis* (Umbrella sedge)	**Not tested*
Bidens frondosa (Beggars tick)	*Solanum americanum* (Small-flowered nightshade)		
Erigeron sumatrensis (Broadleaved fleabane previously named *Conyza sumatrensis)*			
Lotus pedunculatus (Lotus)			

Ludwigia peploides (Primrose willow)			
Symphyotrichum subulatum (Sea aster)			

1.2.2 Seed longevity

The AgResearch report (#12167, DOC-6688874) "***Cuscuta campestris* seedbank evaluation from Lake Whangape and Whangamarino Wetland, Waikato region, NZ**" provided results of seed longevity tests of scarified *C. campestris* seed following Kew Garden test protocols. Results indicated a field persistence of half of the seed population to be 1 to 3 years (P_{50}=20) with a proportion of the seedbank remaining viable from 5 to 10 years (Hackell and James, 2022).

1.2.3 2023 Report

In 2023 the AgResearch report (#12358, DOC-7269772) *"**Cuscuta campestris* – parasitism of *Bolboschoenus fluviatilis***" (June 2023) determined the susceptibility of *B. fluviatilis* as a host to *C. campestris* was low. Pre germinated *C. campestris* seed did not establish on mature *B. fluviatilis* despite numerous attempts. *C. campestris* failed to establish from the ground. The sheath at the base of *B. fluviatilis* providing a physical barrier to parasitism. Haustoria did penetrate the softer green stem from a fragment once during the trial but failed to thrive and died quickly after parasitism occurred therefore mature *B. fluviatilis* was not considered a host of *C. campestris* (Hackell and James, 2023).

Sustaining populations of *C. campestris* at known Waikato sites were therefore most likely supported by other alternative host plant species. Questions remained if *C. campestris* could parasitise the softer stems of the annual, younger *B. fluviatilis* seedlings. This question is addressed in this report.

1.2.4 2024 Report

The purpose of this 2024 report, "***Cuscuta campestris*: Host themes and preferences**" is to further investigate the range of host species and the degree of susceptibility to *C. campestris*. Parasitism levels of various native and exotic plant hosts was examined along with common agricultural and riparian weeds, culturally significant plant hosts, rongoā significant plant hosts and non-host plants. Plants were chosen from a priority list provided by DOC, consideration to common riparian plantings and from species noted in rongoā databases on the Landcare website and books included in the reference list (Murdoch,1994 and Williams 1996).

This report outlines a host preference scoring system to distinguish the level of susceptibility of a host. In addition, host themes, profiles or unique attributes that contribute to determining both non-hosts and host preferences of *C. campestris* were examined.

The aim of identifying *C. campestris* host preferences is to improve management of this weed species. Identifying hosts that sustain *C. campestris* populations will aid targeted control operations. Host range knowledge will elucidate the threat to high value NZ

ecosystems and culturally significant native plants (previously untested). It will also provide direction for non-host species to plant in riparian protection schemes.

2. Method

2.1 Permissions

Cuscuta campestris is an Unwanted Organism in NZ. Permission by Ministry of Primary Industries *Manatu Ahū Matua* (MPI) was required before work could commence. Permission was granted in February 2023 and expires in February 2028. All seeds and plants were kept at AgResearch Ruakura under PC1 containment in agreement with MPI permissions granted. All plant material and soil used in experiments was autoclaved, double bagged and disposed of in biohazard bins.

2.2 Host selection.

Selection of host plants were based on common agricultural weeds, agriculturally significant plant species, and common riparian plant species which are also used in Māori medicine or rongoā. Some specific species were also identified by the Department of Conservation (DOC) as hosts of specific interest (Appendix 7.1). A priority list was provided by DOC as a guide to host testing. Host selection was based on this information, budget constraints and whether seed or plant material could be established before summer 2024.

Potential host plants as well as some known host plants were field collected, brought from a nursery or grown from seed. These host plants (refer Appendix 7.2) were established in individual pots in the glasshouse over winter 2023. The AgResearch, containment glasshouse facility maintains an average daytime temperature of 24°C throughout the year.

In addition, potential hosts from a range of taxonomic families, found at a known *Cuscuta campestris* field site (Churchill Road, Waikato) were selected and brought back to the AgResearch glasshouse containment facility for host testing. Table 2 outlines the themes for host plants and the number of hosts tested within each category.

Table 2: Host categories considered, and number of plants tested for Cuscuta campestris *host suitability.*

Themes considered when host testing	Number of plants tested in each category
Total number of plants	47
Taxonomic families	**26**
Agriculturally significant plants	4
Rongoā	15
Dicots	38
Monocots	9
Exotics	33
Natives	14
Fern	1
Grasses	6
Herbaceous	31

Palm	1
Sedges	3
Shrub-tree	4

2.3 Parasitism

In most cases parasitism was determined by visually identifying haustoria access through the hosts cell wall. This was achieved by slicing hosted plant material longitudinally through *C. campestris* and host and viewing sliced sections under a compound microscope. Where achievable some photographs of these sliced sections and of *C. campestris* on various hosts tested are included in Appendix 7.

2.3.1 Parasitism from seed

Scarified *C. campestris seed* (seed collected from earlier studies <24 months old) was placed on a moist paper towel in a 30-degree incubator. Twenty newly emerging pre-germinated seeds were scattered at the base (within 2cm of host base) of individual potential host plants. Plants were then maintained in the PC1 glasshouse and observed over November 2023 to February 2024. If hosting was unsuccessful this was repeated another two times on separate occasions during this period. If establishment on the host from seed did not occur after three attempts this was assessed and recorded as non-host from seed.

2.3.2 Parasitism from fragment

A 10 cm long *C. campestris* fragment (healthy stem, no haustoria) was placed on potential hosts to ascertain if hosting could occur from above. At the time we were unsure if this could occur and considered parasitism via fragment a potential dispersal mechanism. If hosting was unsuccessful from a single fragment, this was repeated a further two times. Host plants were maintained and monitored over several months to determine if attachment of *C. campestris* from a fragment occurred.

In practice this was difficult to ascertain as C. campestris seemed to host but then died. This led to a change in our original score system to ascertain fragments that survived to flowering, or only vegetatively or if the fragment appeared to grow but then died in under three weeks. No control, where a Cuscuta fragment was monitored to see how long it survived just on soil with no host was considered however literature noted survival of up to three weeks without a host was achievable for *C. epithymum* (Lani and Kogan, 2005).

2.4 Determining host preference: non-hosts, vegetative host, secondary or primary

The susceptibility of a host in this report is defined using both a score system, visual assessment of haustoria through the cell wall and *C. campestris* vigour when growing on a possible host. The 0-4 score system below was used to guide whether a host was a non-host, a vegetative only host, a secondary host or a primary host.

Scoring of hosts was as follows:

0 *= COMPLETE NON-HOST: Did not host from seed or fragment at any time.* ***Determined a non-host.***

1 *= INCOMPLETE NON-HOST: Briefly grew from fragment but died within 3 weeks, showed pour vigour and did not flower.* ***Determined a non-host*** *if only survived less than 3 weeks, no evidence of haustoria through the cell wall or nutrients extracted from host.*

2 *= INCOMPLETE VEGETATIVE ONLY HOST: Briefly grew from fragment or a seed but only developed vegetatively for more than three weeks – no flowering.* ***Determined a vegetative host.***

3 *= OPPORTUNIST COMPLETE HOST****:*** *Did not host directly from seed but successfully hosted from fragment to flowering.* ***Deemed a secondary host.***

4 *= COMPLETE HOST: hosted from seed to flowering.* ***Deemed a primary host.***

Parasitism was defined as a primary or secondary hosts if *C. campestris* could attach haustoria through the cell wall, extract nutrients from the host and complete its lifecycle to flowering. If host attachment occurred by haustoria briefly but *C. campestris* remained vegetative, or if wilting and death of regions of *C. campestris* occurs after attempted parasitism, then *C. campestris* is unable to extract sufficient nutrients from its host to complete its lifecycle and parasitism was considered “incomplete” and either a vegetative incomplete host or a non-host.

Optical and compound microscopic observations and dissection of *C. campestris* on potential host species were also used to determine parasitism levels where haustoria could be viewed as entering the cell wall. Some photographs are provided in Appendix 7.3 and illustrate it was not always clear to distinguish non hosts as growth can occur for up to three weeks from *C. campestris* fragment reserves.

3. Results and Discussion

Table 3 details the host plants tested and host preference (primary host, secondary host, vegetative host, or non-host) by *Cuscuta campestris.*

Results confirm *C. campestris* has a broad host range. Forty-seven host plants were tested from 26 different taxonomic families (Table 4).

Cuscuta campestris host testing found 30 were primary hosts (53% of those tested), 9 (19% of those tested) were classified as secondary hosts, 4 (9%) as vegetative only hosts and just 11 (21%) as non-hosts.

Primary hosts themes were they are mostly common exotic dicot weeds, from a large range of taxonomic families. Non-hosts were generally monocots (Astatt, 1983, also concluded this) but our findings show this isn’t exclusive. *Avena sativa* (oats) is a monocot and was deemed a primary host where a fragment could allow *C. campestris* to complete its lifecycle to flowering stage. Also, although monocots are less preferred, they can occasionally support *C. campestris* vegetatively, albeit weakly for up to 3 weeks, and extend *C. campestris* timeframe for finding a near-by primary hosts to complete its lifecycle.

One explanation for this inconsistency is the physiological plant differences between a monocot and dicot plant. The vascular bundles in a monocot are scattered while in a dicot they are arranged in rings around the stem edge. The probability of moving through the cell wall and then parasitising the vascular bundle in a monocot could therefore be considered less common but not inaccessible. We consider the physiological difference between monocots and dicots as one part of the explanation for the inconsistency of classifying *C. campestris* hosts and non-hosts.

Table 3: Host plants tested and Cuscuta campestris host preference

Host name (exotic species unless indicated otherwise)	Score	Attached from Seed	Attached from Fragment	Complete lifecycle on host	Primary host	Secondary host	Incomplete vegetative host	Non-host
WETLAND PLANTS collected from known *Cuscuta campestris* site.								
Cyperus eragrostis (juvenile)	2	no	yes	no			rare	
Bolboschoenus fluviatilis (juvenile) (Native*)	1	no	yes	no				
Bolboschoenus fluviatilis (mature) (Native)	2	no	Yes (briefly but later died)	no			rare	common
Centipeda aotearoana (Native*)	4	yes	yes	yes				
Cuscuta campestris (dodder)	2	n/a	yes	yes				
Echinochloa crus-galli	1	no	yes (briefly but later died)	no				
Galium palustre	2	yes	yes	no				

Host name (exotic species unless indicated otherwise)	Score	Attached from Seed	Attached from Fragment	Complete lifecycle on host	Primary host	Secondary host	Incomplete vegetative host	Non-host
Gallium divaricatum	4	yes	yes	yes				
Iris pseudacorus	1	no	yes (briefly but later died)	no				
Juncus acuminatus	1	no	yes (briefly but later died)	no				
Ludwigia palustris	4	yes	yes	yes				
Ludwigia peploides	4	yes	yes	yes				
Lythrum hyssopifolia	2	yes	yes	no				
Mentha pulegium	3	no	yes	yes				
Myriophyllum robustum (Native*)	4	yes	yes	yes				
Ranunculus flammula	4	yes	yes	yes				

Host name (exotic species unless indicated otherwise)	Score	Attached from Seed	Attached from Fragment	Complete lifecycle on host	Primary host	Secondary host	Incomplete vegetative host	Non-host
Rorippa palustris (Native*)	3	no	yes	yes				
NATIVES* and RONGOĀ SIGNIIFICANT PLANTS								
Coprosma robusta (Karamu)	4	no	yes	yes				
Cordyline australis (Cabbage tree)	1	no	yes (briefly but later died)	no				
Leptospermum scoparium (Manuka)	1	no	yes (briefly but later died)	no				
Phormium tenax (Harakeke, Flax)	1	no	yes (briefly on soft leaf tip only)	no			only seedling leaf tip briefly but did not persist.	mature plants are not a host
Piper excelsum (Kawakawa)	4	yes	yes	yes				
Pteris tremula (fern - shaking brake)	4	yes	yes	yes (but filaments were thin/weak)				

Host name (exotic species unless indicated otherwise)	Score	Attached from Seed	Attached from Fragment	Complete lifecycle on host	Primary host	Secondary host	Incomplete vegetative host	Non-host
Rhopalostylis sapida (Nikau)	3	no	yes	yes				
**Natives also noted in wetland category above.*								
AGRICULTURALLY SIGNIFICANT HOSTS								
Cichorium intybus (Chicory used as fodder)	1	no	no	no				
Lolium perenne (Ryegrass)	1	no	no	no				
Trifolium repens (White clover)	4	yes	yes	yes				
Trifolium pratense (Red clover)	4	yes	yes	yes				
Avena sativa (Oats)	4	yes	yes	yes				
Zea mays (Maize)	1	no	no	no				

Host name (exotic species unless indicated otherwise)	Score	Attached from Seed	Attached from Fragment	Complete lifecycle on host	Primary host	Secondary host	Incomplete vegetative host	Non-host
COMMON WEED HOSTS								
Calystegia sylvatica (Greater bindweed)	4	yes	yes	Yes				
Cirsium palustre *(Marsh thistle)*	4	yes	yes	yes				
Euphorbia peplus (Milkweed)	4	yes	yes	yes				
Oxalis spp.	4	yes	yes	yes				
Paspalum distichum *(Mercer grass)*	2	no	Briefly yes	no			Unconfirmed haustoria connection. Incomplete flowering	
Plantago lanceolata *(Narrow leaved plantain).*	4	yes	yes	yes				
Ranunculus repens (Creeping buttercup)	4	yes	yes	yes				
Rumex obtusifolius		yes	yes	yes				

Host name (exotic species unless indicated otherwise)	Score	Attached from Seed	Attached from Fragment	Complete lifecycle on host	Primary host	Secondary host	Incomplete vegetative host	Non-host
(Broad-leaved dock)	4							
Solanum nigrum (Black nightshade)	4	yes	yes	yes				
Sonchus oleraceus (Sow thistle)	4	yes	yes	yes				
Stellaria media *(Chickweed)*	4	yes	yes	yes				
Taraxacum officinale (Dandelion)	4	yes	yes	yes				

HOSTS PREVIOUSLY IDENTIFIED FROM EARLIER AgResearch *C. campestris* REPORTS								
Host name (exotic species unless indicated otherwise)	**Score**	**Attached from Seed**	**Attached from Fragment**	**Complete lifecycle on host**	**Primary host**	**Secondary host**	**Incomplete vegetative host**	**Non-host**
Alternanthera philoxeroides (Alligator weed)	3	Not tested	yes	yes				
Bidens frondosa (Beggars tick)	3	Not tested	yes	yes				
Erigeron sumatrensis *(Broad-leaved fleabane)*	3	Not tested	yes	yes				
Persicaria decipiens (Native) (Swamp willow weed)	3	Not tested	yes	yes				
Solanum americanum (Native) (Small-flowered nightshade)	3	Not tested	yes	yes				
Symphyotrichum subulatum (Sea aster)	3	Not tested	yes	yes				

*In addition, based on a priority list provided by DOC (See Appendix), we attempted to test *Salix cinerea* (exotic grey willow) and *Cynodon dactylon* (exotic Indian doab) as potential hosts, but seed/cutting failed to germinate/survive so these could not be tested. However, from the literature *C. dactylon* isn't considered a host, only rarely and weakly been found with *C. campestris.* Our host classification system would likely classify it as a non-host.

Table 4: Summary of categories considered in identifying host preference themes.

Summary of host categories tested			
	Tested	**Number of that category that *Cuscuta campestris* completed its lifecycle**	**% hosted**
Total number of plants	**47**	**30**	**64**
Taxonomic families	26		
Agricultural significant plants	6	3	50
Rongoā	15	9	60
Dicots	38	30	79
Monocots	9	1	11
Exotics	33	23	70
Natives	14	7	50
Grasses	6	0	0
Herbaceous	31	23	74
Sedges	3	0	0
Shrub-tree	4	2	50
Palm	1	1	100
Fern	1	1	100

3.1.1 Observations

Self-parasitism: *Cuscuta campestris* can live 3 weeks before becoming parasitic but does require parasitism to produce seed. In this study we found *C. campestris* can parasitise itself, where the fragment is connected to another host close by, which would enable it to prolong its timeframe for host finding.

Shading: *Cuscuta campestris* growth slowed when well shaded under a canopy. Pre-germinated seeds (early seedling) did not progress to locating a host or to host attachment when under a shade from an established plant canopy (observation: specific shade levels were not accessed). We observed the coiling response of Cuscuta appeared slower under shade conditions and we confirmed this observation later in the literature. Yokoyama et al., (2023) recorded coiling speed of *C. campestris* is reduced under shade. Johnson et al., (2016) noted light cues play an important role in *Cuscuta* host location and attachment. This observation infers larger sized non-host riparian plantings could therefore shade and hinder *Cuscuta campestris* establishment.

3.1.2 NZ native hosts identified.

Previously unknown NZ native hosts were identified in this study. When small, *Piper excelsum* (kawakawa) is a primary host for *C. campestris.* Within the week this native host was smothered by *C. campestris* (see photograph in Appendix 7.3). *Coprosma robusta* (karamu) seedlings were classified as a primary host supporting *C. campestris* to flowering. Young *Rhopalostylis sapida* (nikau) seedlings (5-10cm in height) and *Pteris tremula* (shaking brake fern) were deemed minor hosts. *C. campestris* is therefore a threat to these NZ natives if it was ever to became widely established in New Zealand.

Young seedlings of *Bolboschoenus fluviatilis* are deemed non hosts. It can support *C. campestris* vegetatively (not to flower) from a fragment, but vigour is poor, and it did not host from germinating seed from the soil surface. Regenerative capabilities of *B. fluviatilis* will likely remain, if *C. campestris* is not allowed to create smothering mats from hosting on nearby exotic dicot weeds.

3.1.3 Themes identified for non-hosts.

- Often non-hosts are monocots however this is not exclusive. Our study found *Avena sativa* (oats) was a primary host. As a general theme however, monocots are not a preferred host of *C. campestris*, but in the absence of choice or in different field environments a small degree of parasitism by *C. campestris* could affect its behaviour on monocots in the field.

- Mechanical barriers such as mature woody or hard stems and fibrous sheaths from the base of a plant, such as with mature *B. fluviatilis,* will reduce the likelihood of *C. campestris* parasitism. NZ native *Leptospermum scoparium* (manuka), *Phormium tenax* (flax) and Cordyline australis (cabbage tree) are not considered hosts of *C. campestris* however these plantings could support *C. campestris* if exotic common weed hosts are not thoroughly and regularly controlled during the warmer months of the year.

- Of agricultural significant pasture species tested, *Lolium perenne* (perennial ryegrass), *Cichorium intybus* (fodder chicory) and *Zea mays* (maize) were deemed non-hosts. These 3 species could be considered in productive areas to ring fence or as a buffer zone to *C. campestris* in addition with other weed control measures. Exclusion of *C. campestris* hosts, such as clover species, would obviously need to be avoided if using a ryegrass monocrop as a buffer.

- Riparian planting at *C. campestris* sites should include larger seedlings of manuka, flax and cabbage trees. Shading out of riparian margins by established planting will also reduce *C. campestris* survival as shade reduces its coiling speed reducing its opportunity to find a host. Mature hosts are generally better able to resist parasitism from *C. campestris*.

3.1.4 Weed management

Cuscuta campestris progressive containment is achievable using a combination of weed control methods (preventive, cultural, mechanical, and chemical). The priority aims of weed management where *Cuscuta* wild populations have established is to prevent flowering and seed shed through chemical control (herbicides), manual removal, sustained weed control of exotic dicot hosts and maintaining non-host boundaries to contain sites. Fields with a history of *Cuscuta* infestation need to be monitored frequently and new *Cuscuta* plants controlled before flowering.

Our investigation illustrates weed management plans:

- should look to control soft stemmed dicots and ring fence incursion areas with non-host monocot plants;

- riparian planting considerations should include firm stemmed (lignified) larger monocot non host natives;

- removal of the lower leaves at planting could reduce the incidence of *C. campestris* seedling attachment from the base of plants;

- should consider timing of riparian planting: planting after the germination flush of *Cuscuta* in the spring (seed germination is temperature dependent between 15 to 30°C), or if possible, in autumn, to achieve riparian establishment while *C. campestris* infestations are dormant.

4. Research questions raised by this study

There is still a lot to discover about how *C. campestris* behaves in a New Zealand (NZ) context and how it will impact NZ as our climate changes to suit this parasitic pest plant. Further questions raised by this study include:

- Using dark pigmented plants? A previous study identified *Cuscuta* responds to green chlorophyll and light (Yokoyama et al, 2023) to aid in its host location. *Cuscuta* spp selectively forage and orient themselves to greener healthy plants. They are phototropic towards red: far red ratio (Orr et al, 1996a). Would a darker brown variety of *Phormium tenax* elicit further resistant to Cuscuta fragments than the green variety tested in this study?

- Seed burial or covering? Most seedlings of *C. campestris* emerge from the top 3 cm of soil, with none emerging below 6.5 cm (Allred and Tingey 1964; Hutchinson and Ashton 1980). Sandler et al. (1997) reported that the application of a 2.5 cm layer of sand reduced the seedling emergence of *C. gronovii* in cranberry bogs. Our earlier reports identified the most vulnerable stage of *C. campestris* is at early emergence just after germination. Applying a physical barrier around riparian plants to reduce seedling emergence such as a mulch could be a future area to investigate in managing *C. campestris* seedbanks.

- Moisture required for germination. *Cuscuta* is clearly associated with wetlands, but wetlands also are prone to surface drying from time to time. How do these environments impact *C. campestris* germination? Could water table manipulation be used to manage *Cuscuta* germination? Also, how distant from wetlands is *Cuscuta* likely to still germinate?

- Specific measured yield losses of C. campestris on common New Zealand crops to better establish quantifiable impact.

Going forward the authors would like to pursue further research with DOC and WRC into this complex but potentially destructive sleeper pest plant.

5. References

Atsatt, P.R. 1983. Host-parasite interactions in higher plants. In encyclopaedia of plant physiology, new series, vol 12. C. physiological plant ecology III. Responses to chemical and biological environment (edited by Lange, O.L. et al.) Berlin, Springer-Verlag, 519-535.

Abutarbush, S. M. (2013). Alfalfa dodder (*Cuscuta campestris*) toxicity in horses: clinical, haematological and serum biochemical findings. Vet Rec 173(4): 95.

Adhikary N.K. and B. Patra. (2023). Chapter 19 - Virus-vector interaction with special reference to RNA virus of important crop plants: An appraisal. In: Plant RNA Viruses, edited by R. K. Gaur, B. L. Patil and R. Selvarajan. Academic Press 2023 DOI https://doi.org/10.1016/B978-0-323-95339-9.00018-1

Anonymous author. (Accessed 2024). Chemical control: https://www.agric.wa.gov.au/herbicides/golden-dodder-control?.

Benvenuti, S., Dinelli, G., Bonetti, A., and Catizone, P. (2005). Germination ecology, emergence, and host detection in Cuscuta campestris. Weed Research, 45: 270-278. https://doi.org/10.1111/j.1365-3180.

Dawson J.H., Musselman L.J., Wolswinkel P and Dorr I., (1994). Biology and control of Cuscuta. Reviews of Weed Science 6. 265-317.

Dorr, I. (1987). The haustorium of Cuscuta – new structural results. In Proc. 4th Internat. Sym. Parasitic Flowering Plants, Marburg, Germany. P 163-170.

Hackell, D. and James, Trevor. 2022. *Cuscuta campestris* seedbank evaluation from Lake Whangape and Whangamarino Wetland, Waikato Region, NZ. Client report for the Department of Conservation. Report number 12167, DOC-6688874.

Hackell. D. and James, Trevor. 2023. *Cuscuta campestris* – parasitism of *Bolboschoenus fluviatilis.* Report number 12358, DOC-7269772.

Haidar, M.A., Orr, G.L. & Westra, P. (1997) Effects of light and mechanical stimulation on coiling and prehaustoria formation in Cuscuta spp. Weed Research, 37, 219–228

HAIDAR MA, GHARIB C & SLEIMAN FT. (2010). Survival of weed seeds subjected to sheep rumen digestion. *Weed Research.* 50, 467–471.

Johnson, B.I., De Moraes, Consuelo, M. and Mescher, M.C. (2016). Manipulation of Light spectral quality disrupts host location and attachment by parasitic plants in the genus *Cuscuta*. Journal of Applied Ecology. 53., 794-803.

Kogan, M and Lanini, W. (2005). Biology and management of Cuscuta in crops. Ciencia Investigacion Agraria. 32. 165-180.

Ministry for Primary Industries. Unwanted organism status. (Accessed April 2024). https://pierpestregister.mpi.govt.nz/pests-of-concern/?scientificName=&organismType=&freeSearch=Cuscuta+campestris

Mishra. J.S. (2009). Biology and management of Cuscuta species.Indian Journal of Weed Science. 41: Issue 1&2.

Movsesyan and Azaryan, 1974. Poisoning produced by feeding dodder (*Cuscuta campestris*) to animals. Veterinariya (Moscow), 6,92.

Murdoch, Riley. (1994). Māori healing and herbal. New Zealand ethnobotanical. Viking Sevenseas publishers, Paraparaumu, New Zealand. (Accessed April 2024). https://rauropiwhakaoranga.landcareresearch.co.nz/references/1e64103c-55a7-45a1-bd2c-8603f012fa17#section-bibliographicdetails and Landcare website: https://rauropiwhakaoranga.landcareresearch.co.nz/.

Parker. C. 2008. Cuscuta campestris (field dodder). https://www.cabidigitallibrary.org/doi/10.1079/cabicompendium.17111

Qadir, I. *et al.* (2022). *Cichorium intybus*: A Comprehensive Review on Its Pharmacological Activity and Phytochemistry. In: Masoodi, M.H., Rehman, M.U. (eds) Edible Plants in Health and Diseases. Springer, Singapore. https://doi.org/10.1007/978-981-16-4959-2_12

Rees, S. B., and Harborne, J. B. (1985). The role of sesquiterpene lactones and phenolics in the chemical defence of the chicory plant. Phytochemistry 24: 2225–2231.

Rubin, (1995). Herbicide resistance outside North America and Europe: causes and significance. Proc Int Symp on weed and crop resistance to Herbicides. Cordoba, Spain. 1995. April.

Runyon, JB, Mescher, MC and Moraes, CD. (2006). Volatile chemical cues guide host location and host selection by parasitic plants. *Science.* 313: 1964 – 1967.

Sandler, H.A., Else., M.J. and Sutherland. M. (1997). Application of Sand for inhibition of swamp dodder (*C. gronovii*) seedling emergence and survival on cranberry (Vaccinium macrocarpon). Weed Technol. 11:318-323.

Waikato Regional Pest Management Plan 2022-2032, Tūtohu mahere whakahaere ā-roheo waikato mō ngā kírearea. https://www.waikatoregion.govt.nz/assets/WRC/WRC-2019/RPMP/RPMP-2022.pdf

Westwood, J. H., Yoder, J. I., Timko, M. P., & de Pamphilis, C. W. (2010). The evolution of parasitism in plants. Trends Pl. Sci. 15: 227–235.

Williams. P.M.E. (1996)., te Rongoā Māori - Māori Medicine., Araupo Book, Reed publishing Ltd.

Yokoyama, T., Watanabe, A., Asaoka, M. & Nishitani, K. (2023). Germinating seedlings and mature shoots of *Cuscuta campestris* respond differently to light stimuli during parasitism but not during circumnutation. *Plant, Cell & Environment*, 46, 1774 - 1784. https://doi.org/10.1111/pce.14575

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In addition to this report, a conference presentation was delivered at the 2022 Plant Protection Society Conference in Christchurch to promote awareness of *C. campestris* present at some Waikato sites in NZ and acknowledge the collaboration and research being undertaken between AgResearch and DOC in learning more about this Unwanted Organism within a NZ context. The reference to this conference proceeding is below:

Hackell, D, James, T and Bodmin, K. 2022. Conference presentation: Golden dodder (*Cuscuta campestris*) seed longevity and plant hosts in wetland environments. https://nzpps.org/wp-content/uploads/2022/09/NZPPS-22-conference-programme-and-abstracts-FINAL-110922.pdf

7. Appendix

7.1 Priority list provided by DOC to guide host testing and build future research proposals.

***Cuscuta campestris* research questions for 2022/23 and beyond.** Listed by project title, then order of ranking.

Project title	Target species or topic	Further comments	Origin of idea	Ranking
Cuscuta host testing	*Native purua grass (Bolboschoenus* juveniles) establishing from sward roots and seedlings	Would *Cuscuta* parasitise *B. fluviatilis* juvenile plants (as opposed to an established mature plants)? If so, how would this impact the native sedges regeneration abilities at Lake Whangape and Whangamarino wetland?	AgResearch 2022 report recommendation	1
Cuscuta host testing	Exotic umbrella sedge (*Cyperus eragrostis*)	Host suitability	DOC exotic species of concern, seen in the field	2
Cuscuta host testing	Native purua grass (*Bolboschoenus fluviatilis*) as a secondary host	*Bolboschoenus* parasitism once *Cuscuta* is established on other hosts	AgResearch 2022 report recommendation	4
Cuscuta host testing	Exotic clover (*Trifolium repens* as well as *T. pratense*)	Host suitability	DOC pasture species of concern	5
Cuscuta host testing	Exotic plantain	Host suitability - the strain being promoted to plant in pasture to reduce greenhouse gas emissions	AgResearch pasture species of concern	6
Cuscuta host testing	Exotic Mercer grass (*Paspalum distichum*)	Host suitability	AgResearch 2022 report recommendation	7
Cuscuta host testing	Exotic Indian doab (*Cynodon dactylon*)	Host suitability	AgResearch concern from previous host testing	8

Project title	Target species or topic	Further comments	Origin of idea	Ranking
Cuscuta host testing	Exotic alligator weed (*Alternanthera philoxeroides*)	Can *Cuscuta* haustoria survive over winter embedded in alligator weed stems? Implications for *Cuscuta* to spread via alligator weed fragments?	AgResearch 2022 report recommendation and question posed by DOC.	9
Cuscuta host testing	Native pink bindweed (*Calystegia sepium* subsp*. roseata*) and exotic great bindweed (*C. sylvatica* subsp. *disjuncta*)	Host suitability	DOC & AgResearch native and exotic species of concern in wetland margins	10
Cuscuta host testing	Exotic buttercup (*Ranunculus repens*)	Host suitability	AgResearch pasture species of concern	12
Cuscuta host testing	Exotic grey willow (*Salix cinerea*) seedlings	Host suitability	DOC exotic species of concern	13
Cuscuta host testing	Native *Carex* juveniles especially *Carex gaudichaudiana, C. secta, C. virgata* or other planting species	Host suitability	DOC native species of concern	14
Cuscuta host testing	Native nahui (*Alternanthera nahui*)	Host suitability. Native species but same genus as alligator weed and present at Lake Whangape	DOC native species of concern	15
Seedbank longevity	Weed management on seedbank longevity. What is the history of weed control at the soil sites sampled in 2021/22 and how is this weed management impacting *Cuscuta campestris* seed bank longevity?	Attempts to answer how the seedbank functions 'in the wild' as opposed to in the lab / Kew Garden process and the effects of weed control creating multiple opportunities for seedling emergence during a season thereby potentially depleting the seedbank at a faster rate. Easily answered by DOC supplying info?	DOC operational question - answer in annual report or next management plan?	3
Seed survival	What is the seed survival in water and	Attempts to answer within site dispersal and	DOC operational question and a research question	11

Project title	Target species or topic	Further comments	Origin of idea	Ranking
	resulting germination rates?	effects of flood events on seed viability		
Climate change	Climate change scenarios and efficacy of recruitment of *Cuscuta* under different future climate regimes.	Attempts to answer queries around seed viability and seedling / plant survival under different climate and CO_2 scenarios.	AgResearch concern	16

7.2 Categories of host plant tested to ascertain themes

Known Rongoā	Māori name	Common name	Scientific name	Taxonomic Family	Dicot or monocot	Growth Habit	Native or Exotic	Established to flowering	Attached from fragment
	Koroua	White clover _Kopu II	*Trifolium repens*	Fabaceae	dicot	Herbaceous	Exotic	yes	yes
	Karaka whero	Red clover	*Trifolium pratense*	Fabaceae	dicot	Herbaceous	Exotic	yes	yes
	Karaehi rae	Perennial ryegrass	*Lolium perenne*	Poaceae	dicot	Grass	Exotic	no	no
	Kanga	Maize	*Zea mays*	Poaceae	monocot	Grass	Exotic	no	no
Rongoā	puha or puwha	Sow thistle	*Sonchus oleraceus*	Asteraceae	dicot	Herbaceous	Exotic	yes	yes
	N/A	Alligator weed	*Alternanthera philoxeroides*	Amaranthaceae	dicot	Herbaceous	Exotic	yes	yes
	N/A	NZ's sneezewort	*Centipeda aotearoana*	Asteraceae	dicot	Herbaceous	Native	yes	yes
	N/A	Beggar’s tick	*Bidens frondosa*	Asteraceae	dicot	Herbaceous	Exotic	yes	yes
	N/A	Sea aster	*Symphyotrichum subulatum*	Asteraceae	dicot	Herbaceous	Exotic	yes	yes
	N/A	Broad-leaved fleabane	*Erigeron sumatrensis*	Asteraceae	dicot	Herbaceous	Exotic	yes	yes
	N/A	Marsh Thistle	*Cirsium palustre*	Asteraceae	dicot	Herbaceous	Exotic	no	yes
Rongoā	poniu	Marsh yellow cress	*Rorippa palustris*	Brassicaceae	dicot	Herbaceous	Native	no	yes
	N/A	Umbrella sedge	*Cyperus eragrostis*	Cyperaceae	dicot	Sedge	Exotic	no	yes
Rongoā	purua grass or kukuraho	Marsh clubrush (juvenile soft green life stage)	*Bolboschoenus fluviatilis*	Cyperaceae	monocot	Sedge	Native	no	briefly then died
	N/A	Umbrella sedge	*Cyperus eragrostis*	Cyperaceae	monocot	Sedge	Exotic	no	briefly then died

Known Rongoā	Māori name	Common name	Scientific name	Taxonomic Family	Dicot or monocot	Growth Habit	Native or Exotic	Established to flowering	Attached from fragment
	N/A	Lotus	*Lotus pedunculatus*	Fabaceae	dicot	Herbaceous	Exotic	yes	yes
	N/A	Stout water milfoil	*Myriophyllum robustum*	Haloragaceae	dicot	Herbaceous	Native	yes	yes
	N/A	Yellow flag Iris	*Iris pseudacorus*	Iridaceae	monocot	Herbaceous (juvenille)	Exotic	no	briefly then died
	N/A	Sharp-fruited rush	*Juncus acuminatus*	Juncaceae	monocot	Grass	Exotic	no	briefly then died
	N/A	Pennyroyal	*Mentha pulegium*	Lamiaceae	dicot	Herbaceous	Exotic	yes	yes
	N/A	Hyssop loosestrife	*Lythrum hyssopifolia*	Lythraceae	dicot	Herbaceous	Exotic	no	yes
	N/A	Water purslane	*Ludwigia palustris*	Onagraceae	dicot	Herbaceous	Exotic	yes	yes
	N/A	Primrose willow	*Ludwigia peploides*	Onagraceae	dicot	Herbaceous	Exotic	yes	yes
	N/A	Barnyard grass	*Echinochloa crus-galli*	Poaceae	monocot	Grass	Exotic	no	briefly then died
	N/A	Swamp willow weed	*Persicaria decipiens*	Polygonaceae	dicot	Herbaceous	Exotic	yes	yes
	N/A	Lesser spearwort	*Ranunculus flammula*	Ranunculaceae	dicot	Herbaceous	Exotic	yes	yes
	N/A	Marsh bedstraw	*Galium palustris*	Rubiaceae	dicot	Herbaceous	Exotic	yes	yes
	N/A	Slender bedstraw	*Gallium divaricatum*	Rubiaceae	dicot	Herbaceous	Exotic	yes	yes
	Tawao	Dandelion	*Taraxacum officinale*	Asteraceae	dicot	Herbaceous	Exotic	yes	yes
Rongoā	Harakeke	Flax	*Phormium tenax*	Linaceae	monocot	Herbaceous	Native	no	briefly then died
Rongoā	Mānuka	Tea tree	*Leptospermum scoparium*	Myrtaceae	dicot	shrub-tree	Native	no	briefly then died
Rongoā	Karamu	Coprosma	*Coprosma robusta*	Rubiaceae	dicot	shrub-tree	Native	yes	yes

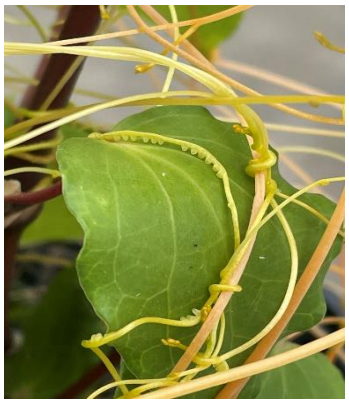
Known Rongoā	Māori name	Common name	Scientific name	Taxonomic Family	Dicot or monocot	Growth Habit	Native or Exotic	Established to flowering	Attached from fragment
Rongoā	Raupeti or or pōporo	Small-flowered nightshade	*Solanum americanum*	Solanaceae	dicot	Herbaceous	Native	yes	yes
Rongoā	Nikau	Nīkau	*Rhopalostylis sapida*	Arecaceae	dicot	Palm	Native	yes	yes
Rongoā	tí kóuka	Cabbage Tree	*Cordyline australis*	Asparagaceae	dicot	shrub-tree	Native	no	briefly then died
	N/A	Creeping oxalis	*Oxalis exilis*	Oxalidaceae	dicot	Herbaceous	Native	yes	yes
	Turawera	Shaking brake	*Pteris tremula fern*	Pteridaceae	dicot	Fern	Native	yes but weakly	yes
Rongoā	Kukuraho	Pūrua grass	*Bolboschoenus fluviatilis (mature plants)*	Cyperaceae	monocot	Grass	Native	no	briefly once then died
Rongoā	Kawakawa	Pepper tree	*Piper excelsum*	Piperaceae	dicot	shrub-tree	Native	yes strongly hosted	yes
Rongoā	Kohukohu	Chickweed	*Stellaria media*	Caryophyllaceae	dicot	Herbaceous	Exotic	yes	yes
Rongoā	Pōhue	Bindweed	*Calystegia* spp.	Convolvulaceae	dicot	Herbaceous	Exotic	yes	yes
Rongoā	Kopakopa	Narrow-leaved plantain	*Plantago lanceolata*	Plantaginaceae	dicot	Herbaceous	Exotic	no	yes
	N/A	Mercer Grass	*Paspalum distichum*	Poaceae	monocot	Grass	Exotic	no	no
Rongoā	Paewhenua	Broad-leaved Dock	*Rumex obtusifolius*	Polygonaceae	dicot	Herbaceous	Exotic	no	yes
	N/A	Giant buttercup	*Ranunculus acris*	Ranunculaceae	dicot	Herbaceous	Exotic	yes	yes
	N/A	Field buttercup	*Ranunculus arvensis*	Ranunculaceae	dicot	Herbaceous	Exotic	yes	yes
	N/A	Milkweed	*Euphorbia peplus*	Euphorbiaceae	dicot	herbaceous	Exotic	yes	yes

7.3 Photographs of *Cuscuta campestris* and some of the hosts identified in this study. Not all hosts are included.

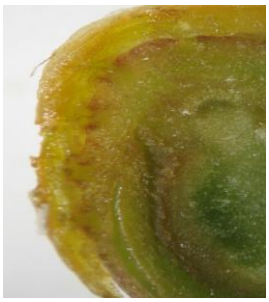
Primary or secondary hosts – can host from seed and fragment to flowering completing the parasitic plant's lifecycle. Others are non-host or incomplete vegetative hosts that may temporarily vegetatively support *C. campestris* but parasitism is incomplete (no viable flowering).

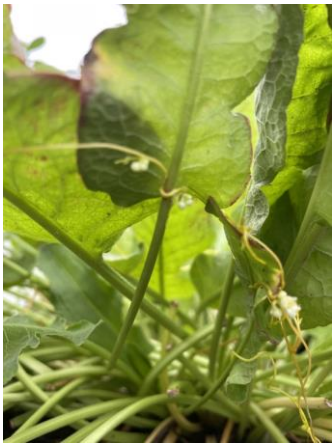
<table>
<tr><td colspan="3">Native</td></tr>
<tr><td>Piper excelsum

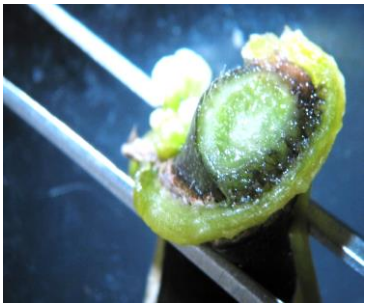
(Kawakawa)

  </td><td>  </td><td>  </td></tr>
<tr><td>  </td><td>  </td><td>C. campestris in stem of kawakawa.

  </td></tr>
</table>

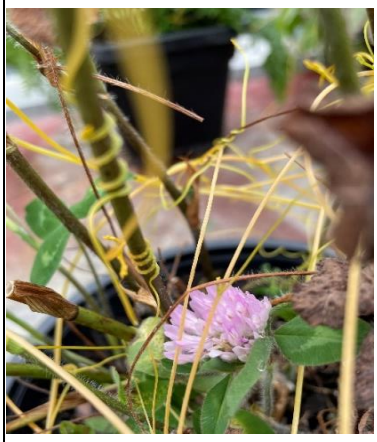
Coprosma robusta (karamu) Complete parasitism hosted to flowering. 	 	 
Rhopalostylis sapida Young nikau Incomplete parasitism. No flowering.		

AGRICUTURAL WEEDS		
Rumex obtusifolius (Broad leaved dock)  Damage response on broad leaf dock visible. 	 	 
Taraxacum officinale (dandelion)		 Leaf dissection showing haustoria penetrated leaf tissue in dandelion stem.

Ranunculus acris (Creeping buttercup) 		
		
Stellaria media (Chickweed)		

Sonchus oleraceus (Sow thistle)		
Solanum nigrum (Black nightshade)		
Euphorbia peplus (Milkweed)		

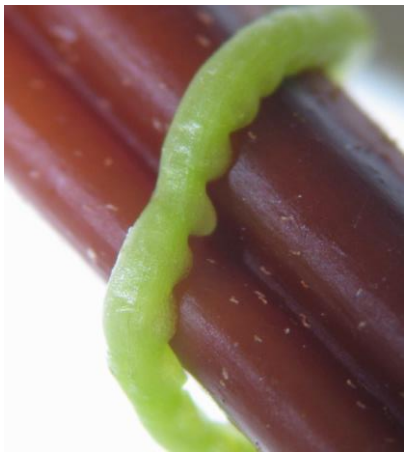
Calystegia sylvatica (Great bindweed)		
Plantago lanceolata (Narrow leaved plantain) Shows a failed attached injury site and haustoria just through the cell wall of the second photo.		
Oxalis spp. 		

Trifolium repens (White clover) 	 On leaf stem  On flower stem	
Trifolium pratense (Red clover) 		

Avena sativa (Oats) Monocot primary host of *C. campestris.* Hosted to flowering albeit weakly.		
Observation of self-parasitism *Cuscuta campestris* on *Cuscuta campestris*		

Secondary hosts. Grown from *Cuscuta campestris* fragments placed on host. Fewer flowers and stem growth was often thinner and weaker than a primary host.

Pteris tremula Fern -shaking brake		

<table>
<tr><td>  </td><td>  </td><td>  </td></tr>
<tr><td colspan="3">This host was interesting as the tendrils wrapped around appeared firmly attached but peel off easily when I pulled at them. Haustoria evident and attached firmly at lower point of stem but couldn't confirm it had penetrated the cell wall when dissected. Later Cuscuta withered and died on these stems. Did manage to flower weakly from a fragment so deemed a minor host.</td></tr>
<tr><td>Paspalum distichum
(Mercer grass)

Non host

This was difficult to judge. C. campestris appeared to be hosting initially but did not form viable flowers and I couldn't confirm haustoria penetrated through the cell wall. Here it used self-parasitism to develop and as the contact was from an established fragment well support by a primary host the energy reserves enable significant growth over a just a few days as see here. Within 3 weeks C. campestris had withered and died and no viable flowers were produced.</td><td>  </td><td>  </td></tr>
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Non hosts

Phormium tenax (Flax) Didn't attach from seed. From a fragment usually withered and died except one time it managed to latch on from a fragment above to the soft leaf tip briefly but within weeks it also died.		
Lepospernum scoparium (Manuka) Did not attach from seed Did coil and grow initially from fragment (as seen) but no evidence of hosting and *C. campestris* died after 1 week. No flowering occurred.		
Cordyline australis (Cabbage tree) Did not attach from seed. Did coil and grow initially from one fragment but this later died after 1 week.		

Juncus acuminatus *(Sharp fruited rush)* Did not attach from seed. Did coil and grow initially from fragment but died after 1 week.