RETROSPECTIVE ANALYSIS OF WORLDWIDE BIOCONTROL PROJECT SUCCESS AND STUDY OF SPECIALIZED SOIL TYPES EFFECTS ON BIOCONTROL AGENT HOST SPECIFICITY

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Abstract

Classical biological control of weeds is an important tool for weed management practiced around the world. However, it is not always successful. Examining historical records of biocontrol efforts would be an alternative approach to understand biocontrol agent and target weed traits correlations with success. The second chapter of this thesis is a review examining life history traits of biocontrol agent and target weed life history traits associated with biocontrol establishment and impact using the 5th edition of '*Biological Control of Weeds: A World Catalogue of Agents and their Target Weeds*' and other reports of biological control agents and target weed traits. This analysis showed that both biocontrol agent and target weed life history traits influenced the success of biological control programs, with the traits of agents more important than those of the weed. The analysis is intended to inform biological control practitioners of the importance agent and weed life history traits for establishment and successful control of weeds. Chapter 2 also revealed that biocontrol candidate agents are typically exposed to test plant species grown in nutrient-rich homogenous soil, but this could influence the susceptibility of herbivory that are adapted to special soil types, for example nutrient-poor metal-rich serpentine soil. Therefore, in the third chapter of this thesis, I tested these hypotheses in our system, the invasive weed, *Lepidium draba* L. (Brassicaeae), several nontarget species related to this weed and a biological control candidate, the stem and petiole gall-forming weevil *Ceutorhynchus cardariae* Korotyeav (Coleoptera: Curculionidae). Results showed that native serpentine soil influenced *C. cardariae* herbivory. Our data show that native species confamilial with the target restricted to specialized soil types may be at less risk of herbivore attack than predicted based on tests conducted in horticultural soil.

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Dedication

To my family!!

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CHAPTER 1 INTRODUCTION

Plant invasions

Globalization and increasing international trade accelerate the movement of non-indigenous plant species around the globe (van Kleunen et al. 2015). More than 13,000 plant species have become naturalized worldwide and North America has received the largest number of naturalized plant species with more than 5,000 species (van Kleunen et al. 2015). Only a small fraction of either purposefully or accidentally introduced plant species naturalize and become invasive (Jeschke and Pyšek 2018; Williamson and Fitter 1996). Invasive plant species are defined as exotic species whose introduction led to naturalization and rapid population increase which causes economic or environmental harm or harm to human health (Thomas and Reid 2007). Invasive plants can have far-ranging consequences for the economy, native biodiversity and ecosystem health and services (Pimentel 2009; Pyšek et al. 2012; Simberloff 2011). For example, plant invaders can have impacts on nutrient cycling and soil properties (Callaway et al. 2004; Liao et al. 2008; Weidenhamer and Callaway 2010), structural change in native habitats (Ehrenfeld 2010; Pyšek et al. 2012; Simberloff 2011), fire regime (e.g. fire frequency and intensity) (Brooks et al. 2004; Mack 2011; Pierson et al. 2011) and food webs (Ehrenfeld 2010; Lau 2013). The increasing accumulation of exotic plant species and their impacts increase the need for respective management efforts (Pimentel 2009; van Kleunen et al. 2015). Herbicide applications are by far the most common management strategy for invasive plants. In addition cultural and mechanical control strategies are useful for small isolated populations of invasive plants (DiTomaso et al. 2006; Kelton and Price 2009). However, these conventional control means require frequent applications over multiple years and often they are not feasible for remote locations and difficult terrain or large infestation because of associated costs (Culliney 2005; Fowler et al. 2000). The use of herbicides also causes collateral or nontarget effects on native and desirable vegetation (Matarczyk et al. 2002; Roshon et al. 1999) and can lead to increased environmental toxicity (Blossey et al. 2001). A potential alternative management strategy is classical biological control, which has been advocated as an economically and ecologically sound self-perpetuating method to mitigate invasive plants (McFadyen 1998; Schwarzländer et al. 2018).

Classical biological control of weeds and worldwide summary

Classical biological control of weeds (hereafter BCW) is defined as the practice of reuniting exotic weeds in the areas where they are invasive with host specific natural enemies from the weed's native range to reduce its vigor, reproductive ability and abundance (Thomas and Reid 2007). BCW can be a sustainable, long-term economical, self-perpetuating and effective method of control invasive plants (Fowler et al. 2000; McFadyen 1998). Worldwide deliberate release efforts for BCW are summarized in the *World Catalog of Agents and their Target Weeds* (Winston et al. 2014). The catalog compiled all deliberately released exotic, or native natural enemies to control exotic weeds and lists biocontrol agents that now occur in regions or countries in which they were not intentionally introduced. Biological control of weeds has been practiced in 150 countries and a total of 601 biological control agents were released against 261 weeds (Winston et al. 2022). In total, 511 exotic biocontrol organisms, including 13 mites, two nematodes, 37 fungi and 459 insect species, were deliberately introduced and released against 210 weed species in 55 plant families worldwide until 2021 (Winston et al. 2022).

The World Catalog data have been summarized with regard to establishment and categorized impact of biological control releases by Schwarzländer et al. (2018). The authors reported that 70.9% of agents established and that 65.7% of targeted weeds experienced some level of control. However, establishment rates of released agents and their impact on target weeds varied among different countries and ranges in which an agent was released. Recently, biocontrol practitioners have emphasized the selection of suitable target weed species and focused on effective biocontrol agents that are more likely to establish and inflict damage to the target weed to maximize project success rates (e. g. McClay 1989a; Sheppard 2003; Sheppard 2006). An assessment of past biocontrol project outcomes with regard to characteristics and traits of biocontrol agents could further improve biological weed control outcomes.

The second chapter of this thesis includes a retrospective analysis of life history traits of biocontrol agents and target weeds, as they relate to biocontrol project outcomes, specifically the establishment of biocontrol agents and impact (damage level) on the target weed. The data basis for this analysis is the data reported in the 5th edition of "*Biological*

Control of Weeds: A World Catalogue of Agents and their Target Weeds" (Winston et al. (2014).

Host specificity testing

Pre-release host specificity testing is being conducted to define the experimental host range, the level of preference for feeding, oviposition, or development of biocontrol candidate species on nontarget plants. The resulting data set is collectively used to predict the likelihood of post-release nontarget attack (Day and Urban 2003; Heard 2002; Marohasy 1998; van Klinken 1999). Various factors such as host-plant interactions, plant demography and abiotic factors (e. g. Briese 2000a; Davis et al. 2006; Impson et al. 2004; Zalucki and Van Klinken 2006), have been considered to reliably assess and predict the environmental safety of biological control candidates post-release, while other environmental factors such as soil chemical properties and soil nutrient condition have received little attention (e. g. Milbrath et al. 2018).

In the third chapter of this thesis, I report a study on the effect of specialized soil types on the performance of a biocontrol candidate on native nontarget plant species confamilial to the target weed that are adapted to specialized soils. The invasive Eurasian perennial herbaceous hoary cress, *Lepidium draba* L. (Brassicaceae), four confamilial nontarget plant species and the Eurasian stem and petiole gall-forming weevil, *Ceutorhynchus cardariae* Korotyeav (Coleoptera: Curculionidae) were used as a model system to study the effects of metalliferous soils on biocontrol candidate performance.

Study system

Lepidium draba

Hoary cress, *Lepidium draba* L. (Brassicaceae), is a Eurasian herbaceous, perennial clonal mustard (Francis and Warwick 2008; Mulligan and Findlay 1974). *Lepidium draba* root system supports numerous aerial shoots, which can grow up to 90 cm tall (Francis and Warwick 2008; Mulligan and Findlay 1974; Mulligan and Frankton 1962). Leaves are sparse to densely pubescent and are irregularly toothed to entire and narrowed towards petiole.

Stems are mostly erect, and branches at the top of the plant give rise to flowering stalks (Francis and Warwick 2008; Mulligan and Frankton 1962). The flower consists of 2-4 cm long four white petals and is in a compact corymb arrangement with very small or no leaves (Francis and Warwick 2008; Mulligan and Frankton 1962). *Lepidium draba* fruits are glabrous silicles and generally have two seeds per pod (Francis and Warwick 2008; Mulligan and Frankton 1962). *Lepidium draba* is a self-incompatible flowering plant favoring obligate-outcrossing (Francis and Warwick 2008; Mulligan and Findlay 1974; Mulligan and Frankton 1962) and can produce large quantities of seeds. For example, a flowering stem of hoary cress can produce up to 850 seed pods (Corns and Frankton 1952; Francis and Warwick 2008) and as many as 17,000 viable seeds per square foot in a single year (McInnis et al. 2003). Although a single plant can produce large quantities of seeds, invasion with vegetative reproduction is the major contributor to patch-size expansion (Gaskin 2006). A study by Kirk et al. (1943) reported that, in the absence of competition, a single plant can produce as much as 400 ramets and spread at a rapid rate covering about a 4 m diameter and have radial growth up to 76 cm annually (Selleck 1965).

Lepidium draba was inadvertently introduced to North America in the late 19th century (Francis and Warwick 2008; Mulligan and Findlay 1974) through seed contaminants and ship-ballast (Bellue 1946; Groh 1940). Since its introduction, *L. draba* has been spreading throughout the country. It is particularly problematic in the western United States, but has also sporadically been reported in the eastern United States (Gaskin et al. 2005a). It is a declared noxious weed in 15 U.S. states (USDA-NRCS 2021a).

Lepidium draba can invade different microsites with soil types ranging from light and coarse sandy to heavy clayey soils and is neutral to alkaline pH levels (Scurfield 1962). Commonly invaded habitats include cropland, pasture and rangelands, roadsides and other disturbed areas. *Lepidium draba* is particularly problematic in irrigated or semi-irrigated crops and pastures (Francis and Warwick 2008; McInnis et al. 2003; Scurfield 1962). *Lepidium draba* invasions have caused economic impacts (McInnis et al. 2003), can serve as alternative host plants to crop pests (Cripps et al. 2006; Mason et al. 2004), impede riparian functions like sediment trapping, bank stabilization, and filtration (Francis and Warwick 2008), displace or decrease native flora genetic diversity and abundance (Mealor et al. 2004), or can inhibit germination and seedling growth of neighboring plant species through root exudates (allelopathy effects) (Caesar 2003; Egli and Olckers 2017). In addition, the plant is toxic to grazing animals as its tissue sulfur concentrations (0.7 to 2.7%) are far above tolerance limits of livestock (≤ 0.4%) (McInnis et al. 2003).

Different management options have been used to control *L. draba*. These include tilling (McInnis et al. 2003; Mulligan and Findlay 1974), repeated grazing using small sheep or goats (Francis and Warwick 2008 and reftherein), hand pulling (Francis and Warwick 2008; Graves-Medley and Mangold 2018), and application of herbicides (Francis and Warwick 2008; Graves-Medley and Mangold 2018). These management practices all control *L. draba* in smaller infestations; however, all these methods are not particularly feasible for large or remote infestations and all of them need to be repeated over multiple years (Ani et al. 2018; Francis and Warwick 2008).

Ceutorhynchus cardariae Korotyaev (Coleoptera, Curculionidae)

Ceutorhynchus cardariae Korotyaev is a Eurasian leaf, petiole, or stem gall-forming weevil (Hinz and Diaconu 2015; Korotyaev 1992). *Lepidium draba* is the only host plant reported in its native range and a field-host range study only found the congener *L. campestre* (L.) W. T. Aiton (Brassicaceae) to also support adult development (Hinz and Diaconu 2015). The weevil is primarily univoltine with a possible second generation (Hinz and Diaconu 2015). Overwintering adult females start to lay eggs in early spring. Lifetime fecundity is on average 125 eggs (Hinz and Diaconu 2015). Female oviposition (sometimes even oviposition attempts) causes the formation of plant galls and the three larval stages feed on parenchymatic tissues within those galls prior to pupating in the soil (Hinz and Diaconu 2015). In the native range, *C. cardariae* development from egg to adult takes about 12 weeks and adults of the F1 generation start to emerge from May onward. Immediately, following emergence weevils begin to feed on *L. draba* foliage and continue to do so for 2-3 weeks before weevils aestivate during the summer, which coincides with *L. draba* senescence (Hinz and Diaconu 2015). Weevils recommence feeding in late August through late fall when they enter hibernation. Gall formation by *C. cardariae* can severely stunt or prematurely kill shoots at higher weevil herbivory intensity, reduce plant vigor and decrease the competitive ability of *L. draba* (Hinz and Diaconu 2015). In addition, *C. cardariae* has a long oviposition period and attacks both phenological stages of *L. draba,* rosette and bolting plants, (Hinz et al. 2006; Hinz and Diaconu 2015), making it difficult for *L. draba* to escape weevil attack.

Ceutorhynchus cardariae host-specificity testing

The experimental host range of *C. cardariae* has been studied at CABI Switzerland since 2003. No-choice-, choice-, and field cage tests have been used to define the experimental host range of *C. cardariae*. Pre-release oviposition, feeding and development tests were conducted with 157 plant species(Weyl et al. 2019a, Unpublished). A total of 112 plant species (~72%) were native to North America (hereafter NA) including 11 federally listed threatened or endangered (hereafter T&E) plant species in the USA (Weyl et al. 2019a, Unpublished). Under no-choice conditions, 45 NA plant species supported gall development to some degree. *Ceutorhynchus cardariae* adults emerged from 26 NA plant species, including the confamilial *Caulanthus anceps* E. B Payson, *C.* flavescens (Hook.) E. B. Payson, *C. inflatus* S.Watson and T&E *Streptanthus glandulosus* subsp. *albidus* Al-Shehbaz, M. S. Mayer & D.W. Taylor (Weyl et al. 2019a, Unpublished). Fourteen NA plant species supported larval development of *C. cardariae* and only seven NA plant species supported adult development of the weevil under choice conditions. In open field tests with eight NA plant species that were grown more than two meters distant to *L. draba,* no nontarget attack was found (Weyl et al. 2019a, Unpublished). Host-specificity data indicate that *C. cardariae* has a broader physiological host range, i.e., plant species that support development of the weevil under no-choice conditions (Schaffner 2001), covering species within all three tribes of the Brassicaceae family (Schwarzländer et al. 2019, Unpublished). However, during open-field tests, *C. cardariae* demonstrated a much narrower ecological host range, i.e., plant species the weevil chooses to attack (Schwarzländer et al. 2019, Unpublished). Generally, *C. cardariae* growth and reproduction was impaired on almost all nontarget plant species when compared to *L. draba* (Schwarzländer et al. 2019, Unpublished).

References

Ani O, Onu O, Okoro G, Uguru M (2018) Overview of biological methods of weed control. In: Radhakrishnan R (ed) Biological approaches for controlling weeds. IntechOpen, London, pp 5-16

Bellue MK (1946) Weed seed handbook. Series VI. Mon Bull Dept Agric State Calif 35:159

Blossey B, Skinner LC, Taylor J (2001) Impact and management of purple loosestrife (*Lythrum salicaria*) in North America. Biodiversity & Conservation 10:1787-1807

Briese D (2000) Impact of the Onopordum capitulum weevil *Larinus latus* on seed production by its host-plant. J Appl Ecol 37:238-246

Brooks ML, D'antonio CM, Richardson DM, Grace JB, Keeley JE, DiTomaso JM, Hobbs RJ, Pellant M, Pyke D (2004) Effects of invasive alien plants on fire regimes. Bioscience 54:677-688

Caesar A (2003) Synergistic interaction of soilborne plant pathogens and root-attacking insects in classical biological control of an exotic rangeland weed. Biol Control 28:144-153

Callaway RM, Thelen GC, Rodriguez A, Holben WE (2004) Soil biota and exotic plant invasion. Nature 427:731-733

Corns WG, Frankton C (1952) Hoary cresses in Canada with particular reference to their distribution and control in Alberta. Sci Agri 32:484-495

Culliney TW (2005) Benefits of classical biological control for managing invasive plants. Crit Rev Plant Sci 24:131-150

Davis AS, Landis DA, Nuzzo V, Blossey B, Gerber E, Hinz HL (2006) Demographic models inform selection of biocontrol agents for garlic mustard (*Alliaria petiolata*). Ecol Appl 16:2399-2410

Day MD, Urban AJ (2004) Ecological basis for selecting biocontrol agents for lantana. In: Cullen JM, Briese DT, Kriticos DJ, Lonsdale WM, Morin L, Scott JK (eds) XI International Symposium on Biological Control of Weeds, Canberra, Australia, 27 Spril- 2 May 2003. CSIRO Entomology, Australia, p 81

DiTomaso JM, Brooks ML, Allen EB, Minnich R, Rice PM, Kyser GB (2006) Control of invasive weeds with prescribed burning. Weed Technol 20:535-548

Egli D, Olckers T (2017) Establishment and impact of insect agents deployed for the biological control of invasive Asteraceae: prospects for the control of *Senecio madagascariensis*. BioControl 62:681-692

Ehrenfeld JG (2010) Ecosystem consequences of biological invasions. Annu Rev Ecol, Evol Syst 41:59-80

Fowler SV, Syrett P, Hill RL (2000) Success and safety in the biological control of environmental weeds in New Zealand. Austral Ecol 25:553-562

Francis A, Warwick SI (2008) The biology of Canadian weeds. 3. *Lepidium draba* L., *L. chalepense* L., *L. appelianum* Al-Shehbaz (updated). Can J Plant Sci 88:379-401

Gaskin JF (2006) Clonal structure of invasive hoary cress (*Lepidium draba*) infestations. Weed Sci 54:428-434

Gaskin JF, Zhang D, Bon M (2005) Invasion of *Lepidium draba* (Brassicaceae) in the western United States: distributions and origins of chloroplast DNA haplotypes. Mol Ecol 14:2331-2341

Graves-Medley M, Mangold J (eds) (2018) Biology, ecology and management of whitetop (*Lepidium* spp.)(Revised). University Extension Publication, Bozeman, MT

Groh H (1940) Turkestan alfalfa as a medium of weed introduction. Sci Agri 21:36-43

Heard TA (2002) Host specificity testing of biocontrol agents of weeds. In: Smith CW, Denslow JE, Hight SD (eds) Proceedings of a workshop on biological control of invasive plants in native hawaiian ecosystems. , Manoa, Hawaii, 2002. Pacific cooperative studies unit. University of Hawaii, pp 21-29

Hinz HL, Borowiec N, Coromoto CY, Cortat G, Cuenot M, Grecu M, Szucs M (2006) Biological control of whitetops, *Lepidium draba* and *L. appelianum.* Annual report, Unpublished. CABI, Switzerland, Delémont

Hinz HL, Diaconu A (2015) Biology and field host range of *Ceutorhynchus cardariae*, a potential biological control agent for *Lepidium draba*. J Appl Entomol 139:168-178

Impson F, Moran V, Hoffmann J (2004) Biological control of an alien tree, *Acacia cyclops*, in South Africa: impact and dispersal of a seed-feeding weevil, *Melanterius servulus*. Biol Control 29:375-381

Jeschke J, Pyšek P (2018) Tens rule. In: Jeschke JM, Heger T (eds) Invasion biology: hypotheses and evidence. CABI Invasive Series. CABI, UK, pp 124-132

Kelton JA, Price AJ (2009) Weed science and management. In: Verheye WH (ed) Soils, plant growth and crop production, in encyclopedia of life support systems (EOLSS), developed under the auspices of the UNESCO. EOLSS Publishers, Oxford, pp 76-101

Kirk LE, Pavlychenko TK, Kossar W (1943) Report of the investigations at the Research Laboratory of Plant Ecology. University of Saskatchewan, Regina, Canada

Korotyaev BA (1992) New and little-known species of weevil (Coleoptera: Curculionidae) from Russia and the adjacent countries. Revue d'Entomologie 71:807-833

Lau JA (2013) Trophic consequences of a biological invasion: do plant invasions increase predator abundance? Oikos 122:474-480

Liao C, Peng R, Luo Y, Zhou X, Wu X, Fang C, Chen J, Li B (2008) Altered ecosystem carbon and nitrogen cycles by plant invasion: a meta-analysis. New Phytol 177:706-714

Mack RN (2011) Cheatgrass. In: Simberloff D, Rejmánek M (eds) Encyclopedia of biological invasions. vol 3. Univ of California Press, Berkeley, pp 108-113

Marohasy J (1998) The design and interpretation of host-specificity tests for weed biological control with particular reference to insect behaviour. Biocontrol News Inf 19:13N-20N

Matarczyk JA, Willis AJ, Vranjic JA, Ash JE (2002) Herbicides, weeds and endangered species: management of bitou bush (*Chrysanthemoides monilifera* ssp. *rotundata*) with glyphosate and impacts on the endangered shrub, *Pimelea spicata*. Biol Conserv 108:133-141

McClay A (1989) Selection of suitable target weeds for classical biological control in Alberta. Selection of suitable target weeds for classical biological control in Alberta. Alberta Environmental Centre, Alberta

McFadyen REC (1998) Biological control of weeds. Annu Rev Entomol 43:369-393

McInnis ML, Kiemnec GL, Larson LL, Carr J, Sharratt D (2003) Heart-podded hoary cress. Rangelands 25:18-23

Mealor BA, Hild AL, Shaw NL (2004) Native plant community composition and genetic diversity associated with long-term weed invasions. West N Am Nat:503-513

Milbrath LR, Davis AS, Biazzo J (2018) Identifying critical life stage transitions for biological control of long-lived perennial *Vincetoxicum* species. J Appl Ecol 55:1465-1475

Mulligan GA, Findlay JN (1974) The biology of Canadian weeds. 3. *Cardaria draba*, *C. chalepensis*, and *C. pubescens*. Can J Plant Sci 54:149-160

Mulligan GA, Frankton C (1962) Taxonomy of the genus *Cardaria* with particular reference to the species introduced into North America. Can J Bot 40:1411-1425

Pierson FB, Williams CJ, Hardegree SP, Weltz MA, Stone JJ, Clark PE (2011) Fire, plant invasions, and erosion events on western rangelands. Rangeland Ecol Manage 64:439-449

Pimentel D (2009) Invasive plants: their role in species extinctions and economic losses to agriculture in the USA. In: Inderjit (ed) Management of invasive weeds. Invading Nature - Springer Series in Invasion Ecology. Springer, Dordrecht, pp 1-7

Pyšek P, Jarošík V, Hulme PE, Pergl J, Hejda M, Schaffner U, Vilà M (2012) A global assessment of invasive plant impacts on resident species, communities and ecosystems: the interaction of impact measures, invading species' traits and environment. Global Change Biol 18:1725-1737

Roshon RD, McCann JH, Thompson DG, Stephenson GR (1999) Effects of seven forestry management herbicides on *Myriophyllum sibiricum*, as compared with other nontarget aquatic organisms. Canadian journal of forest research 29:1158-1169

Schwarzländer M, Hinz HL, Winston RL, Day MD (2018) Biological control of weeds: an analysis of introductions, rates of establishment and estimates of success, worldwide. BioControl 63:319-331

Schwarzländer M, Hinz HL, Winston RL, Weyl P (2019) A petition for the introduction and open-field release of the Gall-forming weevil *Ceutorhynchus cardariae* (Coleoptera: Curculionidae) for the biological control of hoary cress species (*Lepidium draba*, *Lepidium chalepense* and *Lepidium appelianum*) in North America.

Scurfield G (1962) *Cardaria draba* (L.) Desv. J Ecol 50:489-499

Selleck GW (1965) An ecological study of lens-and globe-podded hoary cresses in Saskatchewan. Weeds 13:1-5

Sheppard A (2003) Prioritising agents based on predicted efficacy: beyond the lottery approach. Improving the selection, testing and evaluation of weed biological control agents 7:11-21

Sheppard AW (2006) How to best select an agent for weed biological control. In: Hoddle MS, Johnson MW (eds) The Californian Conference on Biological Control–V, Riverside, USA, 2006. University of California Citrus Research Center and Agricultural Experiment Station, pp 55-65

Simberloff D (2011) How common are invasion-induced ecosystem impacts? Biol Invasions 13:1255-1268

Thomas MB, Reid AM (2007) Are exotic natural enemies an effective way of controlling invasive plants? Trends Ecol Evol 22:447-453

USDA-NRCS (2021) *Cardaria draba* (L.) Desv. United States Department of Agriculture, Natural Resources Conservation Services. https://plants.usda.gov/core/profile?symbol=cadr. Accessed March 3 2021

van Kleunen M et al. (2015) Global exchange and accumulation of non-native plants. Nature 525:100-103

van Klinken RD (2000) Host specificity testing: why do we do it and how we can do it better. In: Van Driesche R, Heard T, McClay A, Reardon R (eds) Proceedings, host specificity testing of exotic arthropod biological control agents: the biological basis for improvement in safety, X international symposium on biological control of weeds, Bozeman, Montana, USA, 1999. Forest Health Technology Enterprise Team, pp 54-68

Weidenhamer JD, Callaway RM (2010) Direct and indirect effects of invasive plants on soil chemistry and ecosystem function. J Chem Ecol 36:59-69

Weyl P, Closça C, Hinz HL, Besomi G (2019) Biological control of whitetops, *Lepidium draba*, *L. chalepense* and *L. appelianum.* Annual report, unpublished. CABI, Delémont, Switzerland

Williamson M, Fitter A (1996) The varying success of invaders. Ecology 77:1661-1666

Winston RL, Schwarzländer M, Hinz HL, Day MD, Cock MJW, Julien M (2014) Biological control of weeds: A world catalogue of agents and their target weeds. 5th edn. Forest Health Technology Entreprise Team, Morgantown, West Virginia

Winston RL, Schwarzländer M, Hinz HL, Day MD, Cock MJW, Julien MH (eds) (2022) Biological control of weeds: A world catalogue of agents and their target weeds (Web version). Based on FHTET-2014-04, USDA Forest Service, Forest Health Technology Enterprise Team. Available at https://www.ibiocontrol.org/catalog/index.cfm.

CHAPTER 2: A REVIEW OF BIOLOGICAL CONTROL AGENT AND TARGET WEED TRAITS ASSOCIATED WITH ESTABLISHMENT AND IMPACT

Abstract

Classical biological control is a sustainable and ecologically sound strategy for the management of alien invasive plants. Improving success rates of weed biocontrol programs is an ongoing effort requiring a variety of different approaches. Previous assessments of life history traits of released biocontrol agents and respective target weeds with regard to agent establishment and impact indicated that certain attributes of agents and target weeds such as agent feeding niche, guild and weed life cycle and methods of reproduction are associated with better control outcomes. Here we examined the past biocontrol projects for correlations between target biocontrol agent and target weed traits that are associated with different levels of achieved control. Data collated in the 5th edition of '*Biological Control of Weeds: A World Catalogue of Agents and their Target Weeds'* were used as the basis for a global analysis. Seven biological control agent traits and four target weed traits, respectively were added to the data set for each biocontrol agent or target weed based on published literature. Analyses of agent establishment showed that biocontrol agent traits were correlated with successful establishment: Biological control agents feeding internally on aboveground plant parts, multivoltine agents, and agent with both, adult and immature feeding life stages had a higher probability of establishment. For weeds, those occurring in aquatic or riparian habitats were associated with higher biocontrol agent establishment rates. Biocontrol agent traits feeding habit, feeding place, feeding parts, feeding niche, feeding guild, voltinism and damaging stages and target weed traits life cycle, propagation modes and ecosystem with the exception of plant growth habit, were strongly correlated with agent impact. Agents included exophytic feeders, feeding on vegetative plant parts, multivoltine agents and biocontrol agents with adult and immature feeding life stages. Perennial weeds, weeds reproducing vegetatively and weeds from aquatic or riparian habitats were associated with greater biocontrol success. This analysis may facilitate biological weed control target prioritization or biological control candidate selection, which in turn could help improving biocontrol project successes. Further investigations to strengthen the predictability of agent control success such as analyzing biocontrol agent and target weed traits in combinations, or inclusion of climatic variability traits would be useful.

Introduction

Globalization of trade and travel have increased the number of invasive plant species around the globe (van Kleunen et al. 2015). As a consequence, impacts caused by invasive plants on the economy, biodiversity and ecosystem services have increased substantially (Pyšek et al. 2020; Simberloff et al. 2013; van Kleunen et al. 2015). Classical biological control of weeds (hereafter BCW) is considered an economically sound and environmentally safe management strategy to control invasive plants (Clewley et al. 2012; Fowler et al. 2000; McFadyen 1998; Schwarzländer et al. 2018). Worldwide, BCW has been implemented in 150 countries and until 2012, a total of 468 biocontrol agent species have been intentionally released for the control of 175 invasive plant species (Winston et al. 2014). Successful control outcomes for BCW projects are well documented (e.g. Julien 1989; Winston et al. 2014) and nearly two third of weed targeted up to 2012 received some level of control (Schwarzländer et al. 2018). However, the level of success is only categorized broadly and for many weed biocontrol projects evaluations of outcomes lack peer reviewed studies (see Winston et al. 2014). One factor influencing the outcome of BCW projects is the difficulty in selecting the most effective biocontrol agents that impose the most damage to a target weed *a priori* (Julien 1989). Similarly, prioritization of target weeds based on their susceptibility to BCW could facilitate more successful project outcomes (but see Canavan et al. 2021; Downey et al. 2021; Paterson et al. 2021). *A posteriori* evaluations of successes and failures of BCW programs still receive relatively little attention (McEvoy and Coombs 1999), despite the fact that broad analyses may reveal agent or target weed patterns that could be used to improve future BCW project success rates. The data compiled in the 5 editions of '*Biological Control of Weeds: A World Catalogue of Agents and their Target Weeds'* (Julien 1982; Julien 1987; Julien 1992; Julien and Griffiths 1998; Winston et al. 2014) provide an ideal opportunity to identify factors associated with biocontrol project outcomes since the data represents an near-complete lists of BCW activities but only few analysis have been conducted: Biocontrol agents within the order Coleoptera especially in the Curculionidae and Chrysomelidae families were more successful than other biocontrol agents (Crawley 1989; von Rütte 2013). Schwarzländer et al. (2018), summarized catalog data and reported a higher establishment rate also for hemipteran biocontrol agents. von Rütte (2013) analyzed 123 weed species and 318 biocontrol agents compiled in the 4th edition of '*Biological Control of*

Weeds: A World Catalogue of Agents and their Target Weeds' (Julien and Griffiths 1998) reported that mainly biocontrol agent life history traits were correlated with the success. Biocontrol agents feeding externally and on vegetative plant tissues were more successful than others. Higher success rates were also reported for agents with multiple generations per year (Cullen et al. 2022; von Rütte 2013). A recent catalog-based analysis of effectiveness of 288 biocontrol agents released in Australia (Cullen et al. 2022) reported that agent feeding guild and target weed growth habits were correlated with the biocontrol success. Biocontrol agents that feed on root/crown and sap feeders control target were effective and herbaceous perennial plants were more amenable to control (Cullen et al. 2022). Paynter et al., (2012) found in a study not based on the catalog data that BCW projects against plants reproducing only vegetatively, including apomictic plants and those in aquatic ecosystems were more successful. Other reviews found that biocontrol was more successful for perennials weeds (McClay, 1989) or that herbaceous weeds could be more successfully managed using BCW than shrubs or trees (Straw and Sheppard 1992).

In this study, we used biocontrol projects from the 5th edition of '*Biological Control of Weeds: A World Catalogue of Agents and their Target Weeds'* (Winston et al. 2014) and added data for seven biocontrol agent traits and four target weed life history traits, respectively (see Appendix C and D for agent and weed traits, respectively for references). Our aim was to analyze whether biocontrol agent or targeted weed life history traits are associated with higher biocontrol agent establishment rates or impact. Our hypotheses were that weed biocontrol success depends upon 1) tissue type attacks, 2) whether agent attack in external or internal, 3) voltinism of agent, 4) terrestrial or aquatic weeds, 5) methods of weed reproduction (details in materials and methods section).

Materials and Methods

Data Source

This analysis used an updated version of the 5th edition of '*Biological Control of Weeds: A World Catalogue of Agents and Their Target Weeds*' (Winston et al. 2014; Winston et al. 2022) (hereafter, the catalog). The catalog compiles all deliberate weed biocontrol releases worldwide with detailed information on release year(s) country of origin of the biocontrol agent(s), etc. As such, it provides a complete list of targeted weed species and biocontrol agent species released. While updating the catalog is an ongoing effort (Winston et al. 2022), we used for the purpose of this analysis all agent species released from pre 1900 until 2012 i.e., data included in the printed version of the 5th edition of the catalog (Winston et al. 2014). The catalog is formatted by agent releases rather than biocontrol agent species released. Often, the same biocontrol agent species was released in different countries or more than once in the same country (Winston et al. 2014). The curators of the catalog treated releases as individual cases when one of the following criteria applied: 1) the same agent was released in a different country, 2) the same agent was released in the same country but from a different source, 3) the same agent was released within the same country and from the same source but for a different weed, or 4) the same agent was released in the same country, but at least five years apart (Winston et al. 2014). For this analysis, we only considered biocontrol agents from the weed's native range that were intentionally introduced and we included only insects and mites as agents. In total we considered 1,498 releases of 436 biocontrol agent species (426 insects and 10 mites) against 171 target weeds in 48 plant families (Winston et al 2014).

Biological control agent and weed life history trait data

Updated establishment and impact data of each releases/ projects listed in the 5th edition of catalog information were directly imported from the catalog (Winston et al. 2014). We added information on different life history traits for each biocontrol agent and target weed species by searching species names in Google, Google Scholar or the CABI Invasive Species Compendium (CABI 2022). We used published literature, unpublished technical reports and in a few cases extension publications as references for each trait value of each biocontrol agent or weed. If information for a biocontrol agent or a weed differed between their respective native and introduced range(s), only information for the introduced range was considered (Reference lists for biocontrol agent and target weed life history trait information are provided as Appendix C and Appendix D, respectively). The biocontrol agent traits used for the analysis were: 1) Biocontrol agent feeding habit, because earlier studies indicated higher success rates for exophytic feeders (von Rütte 2013); 2) agent feeding guild and 3) feeding niche, because there are assumptions that control success is associated with biocontrol agent feeding on plant vascular systems or mechanical support systems (Goeden 1983; Harris 1973); 4) plant part attacked and 5) plant tissues attacked by biocontrol agents. Based on the reviews that agents attacking vegetative tissues (Harris 1973) and belowground feeders (Blossey and Hunt-Joshi 2003) are associated with greater success; 6) voltinism because there are several studies that indicate that control success is more likely for multivoltine biocontrol agents (Goeden 1983; Harris 1973; Zalucki and Van Klinken 2006); and 7) the number damaging life stages (see Table 1 for details).

For target weeds, the following life history traits were used: 1) life cycle, since it has been proposed that perennial weed species have a better control potential than annual or biennial plants (McClay 1989b; Straw and Sheppard 1992); 2) invaded ecosystem, because studies reported that aquatic weeds have greater control potential than terrestrial plants (Paynter et al. 2012); 3) mode of propagation, because greater biocontrol program success has been linked to plants that only reproduce vegetatively (Burdon and Marshall 1981; Paynter et al. 2012), though Chaboudez and Sheppard (1995) argued that biocontrol success was independent of species reproductive mode; and 4) plant growth habit, because it has been proposed that herbaceous plants are easier to control than shrubs or trees (Straw and Sheppard 1992) (see Table 2.1 for details on traits and their levels; Appendix A and Appendix B for agent and weed traits levels definitions)).

Biocontrol project outcome data

The catalog reports agent establishment and categorically the level of damage inflicted (impact) on target weed for each release recorded (Table 1 in Winston et al. 2014)(Appendix A). For the catalog, curators classified level of control on the target weed based on distribution and abundance of the agent, extent and degree of target weed suppression, and the need of supplementary management practices (Schwarzländer et al. 2018; Winston et al. 2014). For this analysis, we used the impact categories as stated in the catalog (Winston et al. 2014). Establishment of biocontrol agents and impact on the target weed were classified for each release by the catalog curators based on reviews of published literature, if available, or unpublished technical documents and personal communications with subject experts. For this analysis, we included all BWC releases made pre 1900 through

2012, but we updated information on establishment and impact for all releases from the current catalog (Winston et al. 2022).

Establishment of released agents was reported in the catalog under three categories: 1) established, 2) not established, or 3) unknown (Winston et al. 2014; Winston et al. 2022). For this analysis, releases whose establishment was stated as unknown (n=41, 2.5% of all releases), were excluded leaving 1,457 releases for analysis. We then excluded releases that did not result in establishment (n=501) for analysis of biocontrol agent's impacts. Levels of damage inflicted or impacts on target weed were grouped into one of seven categories for those agents that established: too early post release, unknown, none, slight, medium, variable, and heavy. In addition, six releases were categorized as too early post- release for impact estimation and the impact of 69 releases was determined unknown. These releases were excluded from the analysis. The data set analyzed for biocontrol agent's impact on target weed comprised 881 releases. Of the 881 releases, 199 (22.59%) had heavy impact, 127 (14.42%) had medium impact and 182 (20.66%) had variable impact, 306 releases (34.73%) had slight impact, and 67 (7.60%) had no impact on the target weed. We consolidated these five impact categories into three levels because there were insufficient observations for some impact categories regarding certain traits (mode of propagation, plant life cycle, agent feeding place), complicating analyses of data. The three levels are heavy, medium/variable and slight/none (Table 2). Of the 881 releases used for the analysis, 199 (22.59%) had heavy impact, 309 (35.07%) had medium/variable impact and 373 (42.34%) releases had slight or no impact.

Statistical analysis

Information on biocontrol agent released and target weed was summarized by agent order and weed family respectively. Biocontrol agent establishment data (binary yes/no) were analyzed using generalized linear mixed models (SAS Proc GLIMMIX), assuming a binomial distribution with a logit link function. Life history traits for biocontrol agents or weed species were treated as fixed effects while country of a biocontrol project or agent release were considered as random effects. Separate models were fit to individual life history predictor variables to test hypotheses that agent and target weed life history traits could potentially influence the establishment of released biocontrol agents. Pairwise comparisons were used to assess differences in probabilities of establishment. Odds were calculated as the ratio of proportion of successful establishment to proportion of failure.

Given establishment, a categorical model (SAS Proc CATMOD) was used to fit the tabulated impact outcome of each release assuming a multinomial distribution with a generalized logit link. Impact outcome levels were designated as heavy, medium/variable and slight/none. Similar to the establishment analysis, separate models were estimated for agent and weed life-history traits.

All statistical analysis were performed using the statistical software package SAS version 9.4 (SAS Institute, Cary, NC). Detectable effects for all models were determined for test results of $p<0.05$.

Results

Summary of biocontrol agents and target weeds

Through 2012, a total of 426 insect and ten mite species were deliberately released in countries outside their native range to control weeds in 1,498 releases (Fig. 2.1). All biocontrol agents belonged to seven insect orders. Of the 426 insects and mites, 193 species (44.27%) are Coleoptera (Fig. 2.1). Insects from four orders (Coleoptera, Lepidoptera, Diptera and Hemiptera) accounted for 94.0% of biocontrol agent species released and 95.1% of all releases (Fig. 2.1). The water hyacinth weevil, *Neochetina eichhorniae* Warner (Coleoptera: Curculionidae) was the most often released biocontrol agent species with 45 releases. Of the 426 insect and mite species, 156 or 37% belonged to two beetle families the Curculionidae and Chrysomelidae.

A total of 175 invasive plant species within 48 families were or are biological control targets. The largest number of biological control agents was released for the control of *Lantana camera* L. *sensu latu* (Verbenaceae) with 41 (9.4%) of all agents species released. Most of the 175 targeted plants were Asteraceae (44 species or 25.1%) (Fig. 2.2). More than half of the targeted plant species (approximately 53%) were Asteraceae, Cactaceae or Fabaceae (Fig. 2.2).

Biocontrol agent establishment with regard to agent traits

Five of seven biocontrol agent life history traits analyzed were strongly associated with greater biocontrol agent establishment. These were: feeding habit, feeding place, voltinism, damaging life stage(s) and feeding guild (Table 2.3). The results indicated a higher proportion of establishment for biocontrol agents that feed internally and on aboveground plant parts (Table 2.4; Fig 2.3). Similarly, biocontrol agents that were multivoltine and agents with both adult and immature life stages damaging the target weed had higher proportions of establishment (Table 2.4; Fig 2.3). Establishment rates for borers feeding externally did not differ from establishment rates compared to internal feeders (Table 2.4; Fig 2.3). There was no difference in establishment rates between agents feeding on plant reproductive or vegetative plant tissues (Table 2.4; Fig 2.3).

Biocontrol agent establishment with regard to weed traits

For plant life history traits, invaded ecosystem was strongly associated with increased establishment rates of biocontrol agent (Table 2.5). The odds plots indicate a higher likelihood for target weeds in aquatic or riparian ecosystem than for weeds in terrestrial ecosystems (Table 2.6; Fig. 2.4). In contrast, agent establishment was similar regardless of weed reproductive mode, plant life cycle, or growth habit (Table 2.6; Fig. 2.4).

Biocontrol agent impact with regard to agent traits

All biocontrol agent life history traits tested were associated with biocontrol agent impact (Table 2.7). Biocontrol agents that feed externally on target weeds were most frequently associated with heavy impact and the proportion of releases of external feeders inflicting heavy impact was 34% higher than that of internal feeders (Table 2.7; Fig. 2.5A). For guild, feeding by sucking insects was more frequently associated with heavy impact. Similarly, boring and chewing insects were associated with heavy impact (Table 2.7; Fig. 2.5B).

Biocontrol agents feeding on vegetative plant tissues caused more frequently heavy impacts than those feeding on reproductive plant parts (Table 2.7; Fig. 2.5C). Inflorescence feeding was least often associated with heavy impact whereas root and stem feeding caused most heavy impact (Table 2.7; Fig. 2.5D). Overall, the proportion releases of vegetative tissue-feeding biocontrol agents causing heavy impact was 247% higher than that of reproductive tissue-feeding agents (Table 2.7; Fig. 2.5C & D).

Releases of biocontrol agents attacking belowground plant tissues were 57% more frequently associated with heavy impact than releases of biocontrol agent feeding on aboveground plant tissues (Table 2.7; Fig. 2.5E). Insect biocontrol agents with adult and immature life stages feeding on weeds caused heavy impacts most frequently (Fig. 2.5F). Similarly, multivoltine biocontrol agents had more frequently heavy impacts on their respective target weeds, followed by univoltine agents and bivoltine biocontrol agents (Table 2.7; Fig. 2.5G).

Biocontrol agent impact with regard to weed traits

Biocontrol agent impact indicated a strong association with the following weed life history traits: 1) ecosystem, 2) plant life cycle and 3) propagation mode but there was no association between biocontrol impact and weed growth habit (Table 2.8). Biocontrol agents released against target weeds in aquatic or riparian ecosystems were more frequently having heavy impact on their respective target weeds and the proportion of releases against aquatic/riparian weeds causing heavy impacts was 67% higher compared to proportion of biocontrol releases against weeds in terrestrial ecosystems (Table 2.8; Fig. 2.6A, C).

Biocontrol projects against perennial weeds more frequently resulted in heavy impacts and the proportion of releases against perennial weeds inflicting heavy impact was 86% and 193% higher, than those for biennial and annual weeds, respectively (Table 2.8; Fig. 2.5B). Biological control projects for strictly vegetatively reproducing target weeds had more frequently heavy impacts whereas projects against weeds reproducing solely by seed resulted least often in heavy impact outcomes (Table 2.8; Fig. 2.6C).

Discussion

Retrospective analysis of past biocontrol projects shows that the traits of the biological control agent and the target weed life history, influenced the probability of establishment and the level of impact of biocontrol releases on target weeds, similar to previous findings (e. g. Cullen et al. 2022; von Rütte 2013). For the probability of establishment of a biocontrol agent release, agent life history traits may be more important than weed traits. This could be that host specific agent was released from the weed's native range in a enemy free environments and are not resource limited in the invaded region. (e. g. Kéry et al. 2001; Root 1973; Sholes 2008; Stephens and Myers 2012). However, all biocontrol agent and target weed life history traits with the exception of weed growth habit were correlated with biological control release impact.

Biological control agent establishment

Overall, biocontrol agents that feed internally had a higher establishment rate than external feeders such as chewers. Predation and parasitism are two major biotic factors limiting agent establishment and success of biocontrol (Harms et al. 2020) and endophagous insect herbivores may be less likely to suffer from predation and parasitism (Cornell and Hawkins 1995; Paynter et al. 2018). Paynter et al. (2018) reported reduced predation on internally feeding weed biocontrol agents in New Zealand compared to external feeders. Survival of two leaf feeders, the broom leaf beetle (*Gonioctena olivacea* Forster) and the Honshu White admiral butterfly (*Limenitis glorifica* Fruhstorfer), biocontrol agents of Scotch broom (*Cytisus scoparius* (L.) Link) and Japanese honeysuckle (*Lonicera japonica* Thunb.) respectively, increased during predator exclusion experiments (Paynter et al. 2019). In addition, internal feeders may be less affected by abiotic environmental factors e.g. precipitation (e. g. Downey et al. 2021). Although sucking insects are external feeders, their establishment rate was similar to that of borers. This might be due to the ability of sucking insects to avoid predation by dropping off from plants when threatened (Dhileepan et al. 2006).

Our results support the assumptions that multivoltine species are more likely to have a higher establishment rate (Goeden 1983; Harris 1973). Similar results were reported for arthropod biocontrol agents (Zalucki and Van Klinken 2006). And biocontrol agents with both, adult and immature life stages feeding on the respective target weed had a higher probability of establishment. A similar result was reported by Forno & Julien (2000) in an analysis of aquatic WBC programs worldwide. The analysis indicated a higher likelihood of establishment for biocontrol agents on weeds of aquatic/riparian ecosystem (Forno & Julien 2000).

Biological control agent impact

Overall, externally feeding biocontrol agents, once established were more effective weed biocontrol agents in our analysis compared to internal feeders, supporting previous findings (von Rütte 2013) but contrary to assumption that internal feeders are more likely to inflict effective control (Crawley 1989). It has been speculated that external feeders may facilitate secondary infections and cause additional damage to weeds, as has been observed in cacti (Moran and Zimmermann 1984), or in corn (Kurtz et al. 2010) or that greater damage may be the result of the higher fecundity of exophytic feeders, which could compensate for predation (Cornell and Hawkins 1995). Our analysis showed that exophytic feeders (139.77 ± 1.03, mean eggs/generation ± SE) had a higher fecundity (approximately two-fold of that of endophytic feeders (204.38 ± 1.04, mean eggs/generation ± SE) (t_{787}= -6.51, P< 0.0001). Among external feeders, biocontrol agents in the sucking guild seem to be promising for successfully controlling weeds. Sucking insects have the capability to inflict damage to host plants through direct feeding damage and indirectly through the direct or indirect transmission of plant pathogens and viruses (Dhileepan et al. 2006; von Rütte 2013). In addition, sucking insect attributes such as short life cycles, high intrinsic rate of increase (Dhileepan et al. 2006) and good dispersal ability (Williams et al. 2008) may further contribute to their better probability of effectiveness.

With regard to plant tissues attacked, our analysis implies that biocontrol agent feeding on plant vegetative tissues may be more effective in inflicting heavy damage to the target weed than feeding on reproductive structures, supporting Harris (1973) assumption that agent feeding on vegetative tissue control target weeds effectively by direct feeding damage and increasing plants vulnerability to secondary infections (e. g. Caesar 2003). It has long been argued that agents feeding on or destroying vascular or mechanical support tissues are more likely to control target weeds (Goeden 1983; Harris 1973), however there are few studies testing that hypothesis directly (Goeden and Ricker 1979). Insect feeding on plant reproductive structures and inflorescence are less likely to inflict heavy damage. Potential explanations for the ineffectiveness of reproductive tissue feeders range from the unavailability of reproductive structures during the breeding period of the biocontrol agent (Impson et al. 2021), the lack of seed-limited population biology of weeds (Impson and Hoffmann 2019; Kéry et al. 2001), to long-lived and large seed banks like that for Australian *Acacia* species, or *Onopordium* thistles (Briese 2000b; Impson et al. 2004). However, other authors have stressed the importance of the supplementary role of inflorescence feeders in reducing seed banks, seedling recruitment, and spread of weeds (Impson et al. 2021; Impson and Hoffmann 2019; Milbrath et al. 2018).

Biocontrol agents that feed on belowground plant tissues are more likely to be effective in controlling target weeds, as proposed by Blossey & Hunt-Joshi (2003). Root herbivory helps suppressing weeds by disrupting crucial functions of plants such as resource uptake, reserve storage and it exposes the plant to other biotic and abiotic stresses (Blossey and Hunt-Joshi 2003; Caesar 2003). Other studies found that root herbivores have a lower risk of predation compared to aboveground herbivores and that the spatial niche potentially could protect root herbivores better from adverse environmental conditions aboveground (Egli and Olckers 2017; Feeny 1976; Simelane 2010).

Biocontrol agents with adult and immature life stages feeding on a weed are more likely to inflict effective control, in line with Forno & Julien (2000) who stated that effective control is more likely with biocontrol agent with both adult and immatures damaging the target weeds. For example, *Agasicles hygrophila* Selman & Vogt adult and immatures feeding on aquatic weed, *Alternenthera philoxeroides* caused heavy damages, while *Macrorrhina endonephele* (Hampson) immatures caused either medium or variable damages (Winston et al. 2014). Adult and immature life stage feeding simply lengthen the duration of time the plant is exposed to herbivory (Forno and Julien 2000). In addition, when the adults and immature stages feed on different plant tissues this could additionally harm the plants (e. g. *Octotoma scabeipennis* Guérin-Méneville, (Coleoptera: Chrysomelidae) adults chew leaves and larvae mine the leaves, Johns et al. 2003, . Our data also suggest that multivoltine biocontrol agents would be more likely to provide effective control of weeds, following speculations that Harris (1973) made.

Our study supports reports made elsewhere (e. g. Paynter et al. 2012) that weeds in aquatic or riparian habitats experience more damage or are more successfully controlled by biocontrol agents than weeds occurring in other ecosystems. Paynter et al, (2012) similarly found that higher control success of aquatic or wetland weeds compared to terrestrial weeds. Majority of releases of control agent against aquatic weed were only on few weed species such as *Salvina molessta* D. S. Mitch, *Pontederia crassipes* Mart. These weeds, which are invasive in many countries have received a greater number of releases compared to weeds that were limited to a few countries and since a number of these were successful, it may bias comparisons of successful between aquatic and terrestrial weeds. For example, *P. crassipes* received almost half of all releases for weeds in aquatic ecosystems (118 of 243 releases) (Winston et al. 2014). Other factors that might have contributed to the success of biocontrol in aquatic ecosystems may include wind and waves, which may in larger water bodies fragment the biocontrol agent-stressed waterweed stands (Cilliers et al. 2003).

Our data suggest that weeds that are reproducing only vegetatively may be more suitable targets for BCW. This may be due to lower genetic diversity or plasticity of vegetatively reproducing weeds in comparison to sexually reproducing plants (Burdon and Marshall 1981). However, in a different study weed biocontrol success was found to be independent of reproductive mode (Chaboudez and Sheppard 1995; Li and Ye 2006). Detail studies on modes of reproduction and genetic plasticity of weeds in their invaded ranges (in comparison to their native ranges), are increasingly conducted (Gaskin et al. 2011; Gaskin et al. 2005b), and should probably be part of any BCW program in order to relate biocontrol success or failure to this weed reproductive trait. McClay (1989b) assumed in a study on agriculturally important weeds in Canada that biennial and perennial weeds are better control targets. This may be that perennial plants are more apparent in spatiotemporal scale (Feeny 1976; Martini et al. 2021; Sholes 2008). Our data support the notion that perennial weeds are more suitable targets than annual weeds.

With greater demands on return on investments and in order to improve outcomes of weed biocontrol programs, the results of this analysis may aid biocontrol practitioners in efforts to prioritize biological control projects based on target weed traits and available agent candidate species if known. The data presented are only based on association of increased probabilities and as such are not strongly indicative by any means. Practitioners will need to give preference first to factors such as agent host specificity, climate matching and economic and public health aspects of invasive weeds when selecting BCW projects before considering biological traits of candidate agents or potential target weeds.

Predicting agent establishment rates and successful BCW outcomes may be enhanced by analyzing agent and weed traits in combination. For example, the benefit of foliage feeding insects have been documented for annual weeds (Day and Urban 2003; Harris 1973; Harris 1991). We were not able to predict that associations based on our analysis because life history traits were only analyzed individually. We anticipate with biocontrol researchers continuing to update the online version of the catalog and an increasing number of quantitative BCW outcome analyses, larger and more comprehensive analyses will be possible. The biocontrol agent and weed trait data collected for this analysis along with its references will be shared with the curators of the catalog as a step to facilitate future analysis.

References

Blossey B, Hunt-Joshi TR (2003) Belowground herbivory by insects: influence on plants and aboveground herbivores. Annu Rev Entomol 48:521-547

Briese D (2000) Impact of the Onopordum capitulum weevil Larinus latus on seed production by its host-plant. J Appl Ecol 37:238-246

Burdon J, Marshall D (1981) Biological control and the reproductive mode of weeds. J Appl Ecol:649-658

CABI (2022) CABI Invasive Species Compendium. https://www.cabi.org/ISC/.

Caesar A (2003) Synergistic interaction of soilborne plant pathogens and root-attacking insects in classical biological control of an exotic rangeland weed. Biol Control 28:144-153

Canavan K, Paterson ID, Ivey P, Sutton GF, Hill MP (2021) Prioritisation of targets for weed biological control III: a tool to identify the next targets for biological control in South Africa and set priorities for resource allocation. Biocontrol Sci Technol 31:584-601

Chaboudez P, Sheppard AW Are particular weeds more amenable to biological control? A reanalysis of mode of reproduction and life history. In: Proceedings of the Eighth International Symposium on Biological Control, 1995. DSIR/CSIRO, pp 95-102

Cilliers CJ, Hill MP, Ogwang JA, Ajuonu O (2003) Aquatic weeds in Africa and their control. Biological control in IPM systems in Africa:161-178

Clewley GD, Eschen R, Shaw RH, Wright DJ (2012) The effectiveness of classical biological control of invasive plants. J Appl Ecol 49:1287-1295

Cornell HV, Hawkins BA (1995) Survival patterns and mortality sources of herbivorous insects: some demographic trends. The American Naturalist 145:563-593

Crawley MJ (1989) Insect herbivores and plant population dynamics. Annu Rev Entomol 34:531-562

Cullen J, Sheppard A, Raghu S (2022) Effectiveness of classical weed biological control agents released in Australia. Biol Control 166:104835

Day MD, Urban AJ (2004) Ecological basis for selecting biocontrol agents for lantana. In: Cullen JM, Briese DT, Kriticos DJ, Lonsdale WM, Morin L, Scott JK (eds) XI International Symposium on Biological Control of Weeds, Canberra, Australia, 27 Spril- 2 May 2003. CSIRO Entomology, Australia, p 81

Dhileepan K, Trevino M, Snow L (2006) Application to release the leaf-sucking bug Carvalhotingis visenda (Hemiptera: Tingidae), a potential biological control agent for cat’s claw creeper Macfadyena unguis-cati (Bignoniaceae). Alan Fletcher Research Station, Queensland Department of Natural Resources, Mines and Water, Brisbane:26

Downey PO, Paterson ID, Canavan K, Hill MP (2021) Prioritisation of targets for weed biological control I: a review of existing prioritisation schemes and development of a system for South Africa. Biocontrol Sci Technol 31:546-565

Egli D, Olckers T (2017) Establishment and impact of insect agents deployed for the biological control of invasive Asteraceae: prospects for the control of Senecio madagascariensis. BioControl 62:681-692

Feeny P (1976) Plant Apparency and Chemical Defense. In: Wallace JW, Mansell RL (eds) Biochemical Interaction Between Plants and Insects. Springer US, Boston, MA, pp 1-40. doi:10.1007/978-1-4684-2646-5_1

Forno I, Julien M (2000) Success in biological control of aquatic weeds by arthropods. In: Biological control: measures of success. Springer, pp 159-187

Fowler SV, Syrett P, Hill RL (2000) Success and safety in the biological control of environmental weeds in New Zealand. Austral Ecol 25:553-562

Gaskin JF, Bon M-C, Cock MJ, Cristofaro M, De Biase A, De Clerck-Floate R, Ellison CA, Hinz HL, Hufbauer RA, Julien MH (2011) Applying molecular-based approaches to classical biological control of weeds. Biol Control 58:1-21

Gaskin JF, ZHANG DY, BON MC (2005) Invasion of Lepidium draba (Brassicaceae) in the western United States: distributions and origins of chloroplast DNA haplotypes. Mol Ecol 14:2331-2341

Goeden R (1983) Critique and revision of Harris' scoring system for selection of insect agents in biological control of weeds. Protection Ecology 5:287-301

Goeden R, Ricker D (1979) Field analyses of Coleophora parthenica (Lep.: Coleophoridae) as an imported natural enemy of Russian thistle, Salsola iberica, in the Coachella Valley of southern California. Environ Entomol 8:1099-1101

Harms NE, Cronin JT, Diaz R, Winston RL (2020) A review of the causes and consequences of geographical variability in weed biological control successes. Biol Control:104398

Harris P (1973) The selection of effective agents for the biological control of weeds. The Canadian Entomologist 105:1495-1503

Harris P (1991) Classical biocontrol of weeds: Its definitions, selection of effective agents, and administrative-political problems.

Impson F, Kleinjan C, Hoffmann J (2021) Suppression of seed production as a long-term strategy in weed biological control: The combined impact of two biocontrol agents on Acacia mearnsii in South Africa. Biol Control 154:104503

Impson F, Moran V, Hoffmann J (2004) Biological control of an alien tree, Acacia cyclops, in South Africa: impact and dispersal of a seed-feeding weevil, Melanterius servulus. Biol Control 29:375-381

Impson FA, Hoffmann JH (2019) The efficacy of three seed-destroying Melanterius weevil species (Curculionidae) as biological control agents of invasive Australian Acacia trees (Fabaceae) in South Africa. Biol Control 132:1-7

Johns CV, Beaumont LJ, Hughes L (2003) Effects of elevated CO2 and temperature on development and consumption rates of Octotoma championi and O. scabripennis feeding on Lantana camara. Entomol Exp Appl 108:169-178

Julien M (1989) Biological control of weeds worldwide: trends, rates of success and the future.

Julien MH (1982) Biological control of weeds—a world catalogue of agents and their target weeds, 1st edn. CABI International, Wallingford

Julien MH (1987) Biological control of weeds—a world catalogue of agents and their target weeds, 2nd edn. CABI International, Wallingford

Julien MH (1992) Biological control of weeds worldwide: trends, rates of success and the future, 3rd edn. Oxford University Press, Oxford

Julien MH, Griffiths MW (1998) Biological control of weeds: a world catalogue of agents and their target weeds, 4th edn. CABI International, Wallingford

Kéry M, Matthies D, Fischer M (2001) The effect of plant population size on the interactions between the rare plant Gentiana cruciata and its specialized herbivore Maculinea rebeli. J Ecol 89:418-427

Kimberling DN (2004) Lessons from history: predicting successes and risks of intentional introductions for arthropod biological control. Biol Invasions 6:301-318

Kurtz B, Karlovsky P, Vidal S (2010) Interaction between western corn rootworm (Coleoptera: Chrysomelidae) larvae and root-infecting Fusarium verticillioides. Environ Entomol 39:1532-1538

Li J, Ye W-H (2006) Genetic diversity of alligator weed ecotypes is not the reason for their different responses to biological control. Aquat Bot 85:155-158

Martini F, Aluthwattha ST, Mammides C, Armani M, Goodale UM (2021) Plant apparency drives leaf herbivory in seedling communities across four subtropical forests. Oecologia 195:575-587

McClay A (1989) Selection of suitable target weeds for classical biological control in Alberta. Selection of suitable target weeds for classical biological control in Alberta

McEvoy PB, Coombs EM (1999) Biological control of plant invaders: regional patterns, field experiments, and structured population models. Ecol Appl 9:387-401

McFadyen REC (1998) Biological control of weeds. Annu Rev Entomol 43:369-393

Milbrath LR, Davis AS, Biazzo J (2018) Identifying critical life stage transitions for biological control of long-lived perennial Vincetoxicum species. J Appl Ecol 55:1465-1475

Moran V, Zimmermann H (1984) The biological control of cactus weeds: achievements and prospects. Biocontrol News and Information (UK)

Paterson ID, Hill MP, Canavan K, Downey PO (2021) Prioritisation of targets for weed biological control II: the South African Biological Control Target Selection system. Biocontrol Sci Technol 31:566-583

Paynter Q, Fowler SV, Groenteman R (2018) Making weed biological control predictable, safer and more effective: perspectives from New Zealand. BioControl 63:427-436

Paynter Q, Overton JM, Hill RL, Bellgard SE, Dawson MI (2012) Plant traits predict the success of weed biocontrol. J Appl Ecol 49:1140-1148

Paynter Q, Peterson P, Cranwell S, Winks CJ, McGrath Z (2019) Impact of generalist predation on two weed biocontrol agents in New Zealand. New Zealand Plant Protection 72:260-264

Pyšek P, Hulme PE, Simberloff D, Bacher S, Blackburn TM, Carlton JT, Dawson W, Essl F, Foxcroft LC, Genovesi P (2020) Scientists' warning on invasive alien species. Biological Reviews 95:1511-1534

Root RB (1973) Organization of a plant-arthropod association in simple and diverse habitats: the fauna of collards (Brassica oleracea). Ecol Monogr 43:95-124

Schwarzländer M, Hinz HL, Winston RL, Day MD (2018) Biological control of weeds: an analysis of introductions, rates of establishment and estimates of success, worldwide. BioControl 63:319-331

Sholes OD (2008) Effects of associational resistance and host density on woodland insect herbivores. J Anim Ecol:16-23

Simberloff D, Martin J-L, Genovesi P, Maris V, Wardle DA, Aronson J, Courchamp F, Galil B, García-Berthou E, Pascal M (2013) Impacts of biological invasions: what's what and the way forward. Trends Ecol Evol 28:58-66

Simelane DO (2010) Potential impact of an introduced root-feeding flea beetle, Longitarsus bethae, on the growth and reproduction of an invasive weed, Lantana camara. Biol Control 54:114-118

Stephens AE, Myers JH (2012) Resource concentration by insects and implications for plant populations. J Ecol 100:923-931

Straw N, Sheppard A (1995) The role of plant dispersion pattern in the success and failure of biological control. In: Delfosse ES, Scott RR (eds) Proceedings of the Eighth International Symposium on Biological Control of Weeds, Linclon University, Cantebury, New Zealand, 2-7 February 1992. DSIR/CSIRO, Melbourne, pp 161-168

van Kleunen M et al. (2015) Global exchange and accumulation of non-native plants. Nature 525:100-103

von Rütte J (2013) Biocontrol: Possible reason for sucess. Thesis, University De Fribourg

Williams H, Neser S, Madire L (2008) Candidates for biocontrol of Macfadyena unguis-cati in South Africa: biology, host ranges and potential impact of Carvalhotingis visenda and Carvalhotingis hollandi under quarantine conditions. BioControl 53:945-956

Winston RL, Schwarzländer M, Hinz HL, Day MD, Cock MJW, Julien M (2014) Biological control of weeds: A world catalogue of agents and their target weeds. 5th edn. Forest Health Technology Entreprise Team, Morgantown, West Virginia

Winston RL, Schwarzländer M, Hinz HL, Day MD, Cock MJW, Julien MH (eds) (2022) Biological control of weeds: A world catalogue of agents and their target weeds (Web version). Based on FHTET-2014-04, USDA Forest Service, Forest Health Technology Enterprise Team. Available at https://www.ibiocontrol.org/catalog/index.cfm.

Table 2.1 Biocontrol agent and target weed life history traits and their levels selected for the study of correlation with the agent establishment and impacts on the target weeds

Life history trait	**Levels**	**References**
Biocontrol agent		
Feeding habit	Internal, external	Crawley 1989, von Rutte 2013
Feeding place	Aboveground, belowground	Blossey & Hunt-Joshi 2003
Feeding part	Vegetative, reproductive	Harris 1973
Feeding niche	Root, stem, foliage, inflorescence	Harris 1973; Goeden 1983
Feeding guild	Chewing, borer, sucking, galling	Harris 1973; Goeden 1983
Damaging life stage	Adult & immature, immature	Forno & Julien 2000
Voltinism	Univoltine, bivoltine, multivoltine	Harris 1973; Goeden 1983; Kimberling 2004
Target weed		
Growth habit	Herbs, shrubs, shrubs/tree	Straw &Sheppard 1992
Life cycle	Annual, biennial, perennial	McClay 1989
Invaded ecosystem	Terrestrial, aquatic/riparian	McClay 1989; Straw & Sheppard 1992
Mode of reproduction	Seeds, vegetative, seeds & vegetative	Chaboudez & Sheppard, 1995; Burdon & Marshall 1981

Table 2.2 Biocontrol agent's impact categories and their definitions adopted from Winston et al, (2014) and Schwarzlaender et al, (2018)

Category	Definition
Heavy	If a biocontrol agent inflicts sufficient damage on target weed and no other management measures needed or minimal management measures, if needed are grouped under heavy impact category
Medium	If a biocontrol agent caused some damage to target weed and other management options are needed to supplement biocontrol are assigned a medium impact category
Variable	Impacts were assigned variable impact if an agent release caused heavy damage in some sites or countries/regions and low or medium impact in other sites or countries/regions
Slight	If a biocontrol agent inflicted limited damage or unlikely to have significant impact on weed population
None	No apparent impact on the target weed

Table 2.3 Results for logistic regression ANOVAs testing the influence of biocontrol agent life history traits on agent establishment (established, or not established). Separate models were fitted to each agent trait

Agent trait	Level	*df*	F-value	P-value
Feeding habits	Internal, external	1, 1370	7.22	0.0073
Feeding place	Aboveground, belowground	1, 1370	4.73	0.0297
Feeding part	Reproductive, vegetative	1, 1370	0.15	0.6976
Feeding niche	Foliage, inflorescence, root, stem	3, 1368	1.61	0.1848
Feeding guild	Borer, Chewing, Galling, Sucking	3, 1368	9.11	<0.0001
Damaging stage	Adult & immature, immature only	1, 1370	18.9	<0.0001
Voltinism	Univoltine, bivoltine, multivoltine	2, 1367	14.8	<0.0001

Table 2.4 Predicted probabilities of successful establishment (± SE) for biocontrol agent life history traits from logistic regression analysis. Values are taken from logistic regressions fitted to each trait individually. Pairwise least square mean comparisons were performed for significance within each trait groups at $P \leq 0.05$ and traits denoted by different letter within each trait category differ significantly

Agent trait	Levels	Probability of establishment
Feeding habit	Internal	0.694 ± 0.025a
	External	0.624 ± 0.029b
Feeding place	Aboveground	0.674 ± 0.024a
	Belowground	0.583 ± 0.047b
Feeding part	Reproductive	0.683 ± 0.038
	Vegetative	0.670 ± 0.027
Feeding niche	Foliage	0.677 ± 0.026a
	Inflorescence	0.670 ± 0.037ab
	Root	0.582 ± 0.048ab
	Stem	0.667 ± 0.034b
Feeding guild	Borer	0.700 ± 0.026a
	Chewing	0.557 ± 0.035b
	Galling	0.625 ± 0.047ab
	Sucking	0.734 ± 0.035ac
Damaging life stage	Adult & immature	0.717 ± 0.025a
	Immature	0.060 ± 0.030b
Voltinism	Univoltine	0.592 ± 0.035a
	Bivoltine	0.605 ± 0.032a
	Multivoltine	0.754 ± 0.026b

Table 2.5 Results for logistic regression ANOVAs of agent establishment (established, or not established) evaluating influence of invasive plant life history trait categories. Each trait was fitted individually during logistic regression

Plant trait	Levels	*df*	*F*- value	*P*-value
Growth habits	Herb, shrub, shrub/tree	2, 1369	2.02	0.1324
Life cycle	Annual, biennial, perennial	2, 1369	2.17	0.1148
Ecosystem	Aquatic/riparian, terrestrial	1, 1370	24.09	<0.0001
Propagation	Seed, vegetative, seed & vegetative	2, 1369	0.22	0.8065

Table 2.6 Predicted probabilities of successful establishment (± SE) for each weed life history traits from logistic regression. Values are taken from logistic regressions fitted to each trait individually Pairwise least square mean comparisons were performed for significance within each trait groups at $P \leq 0.05$ and traits denoted by different letter within each trait category differ significantly

Weed traits	Levels	Probability of establishment
Growth habit	Herb	0.6770 ± 0.027
	Shrub	0.6468 ± 0.029
	Shrub/tree	0.7545 ± 0.051
Life cycle	Annual	0.5736 ± 0.053
	Biennial	0.6459 ± 0.051
	Perennial	0.6723 ± 0.023
Propagation	Seed	0.6749 ± 0.030
	Vegetative	0.6801 ± 0.050
	Vegetative & seed	0.6593 ± 0.026
Ecosystem	Aquatic/riparian	0.8027 ± 0.029a
	Terrestrial	0.6141 ± 0.028b

Table 2.7 Results for categorical generalized model ANOVAs of biocontrol agent impact (heavy, medium, variable, slight, none) evaluating the influence of biocontrol agent life history traits

Agent traits	Levels	*df*	$\chi 2$	P-value
Feeding habit	Internal, External	2	6.59	0.0371
Feeding place	Aboveground, Belowground	2	9.78	0.0075
Feeding part	Reproductive, Vegetative	2	42.32	<0.0001
Feeding niche	Foliage, Inflorescence, Root, Stem	6	56.39	<0.0001
Feeding guild	Borer, Chewing, Galling, Sucking	6	26.29	0.0002
Damaging stage	Adult & immature, Immature only	2	97.37	<0.0001
Voltinism	Univoltine, Bivoltine, Multivoltine	4	22.81	0.0001

Table 2.8 Results of categorical generalized logit model ANOVA evaluating the influence of weed life history traits for impact (heavy, medium, variable, slight, none). Significance of each weed trait was determined at $P \leq 0.05$

Weed traits	Levels	*df*	$\chi 2$	P-value
Growth habits	Herb, shrub, shrub/small tree	4	1.68	0.7947
Life cycle	Annual, biennial, perennial	4	17.59	0.0015
Propagation	Seed, vegetative, seed & vegetative	4	25.13	<0.0001
Ecosystem	Aquatic/riparian, terrestrial	2	32.09	<0.0001

Fig. 2.1 Intentional classical biological control agent species and total releases made by insect orders and mites. Black bars represent the biocontrol agent species and white bars represent the proportion of releases for respective agent orders

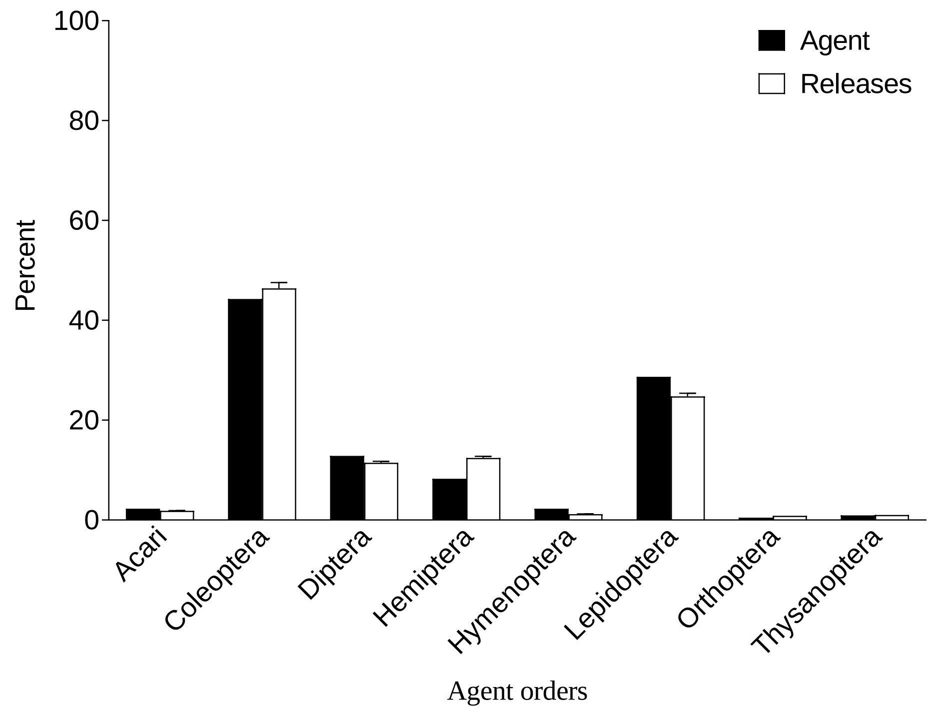


Fig. 2.2 Number of invasive plant species targeted for classical biological control by plant family (plant families with less than 2 target weed species not shown)

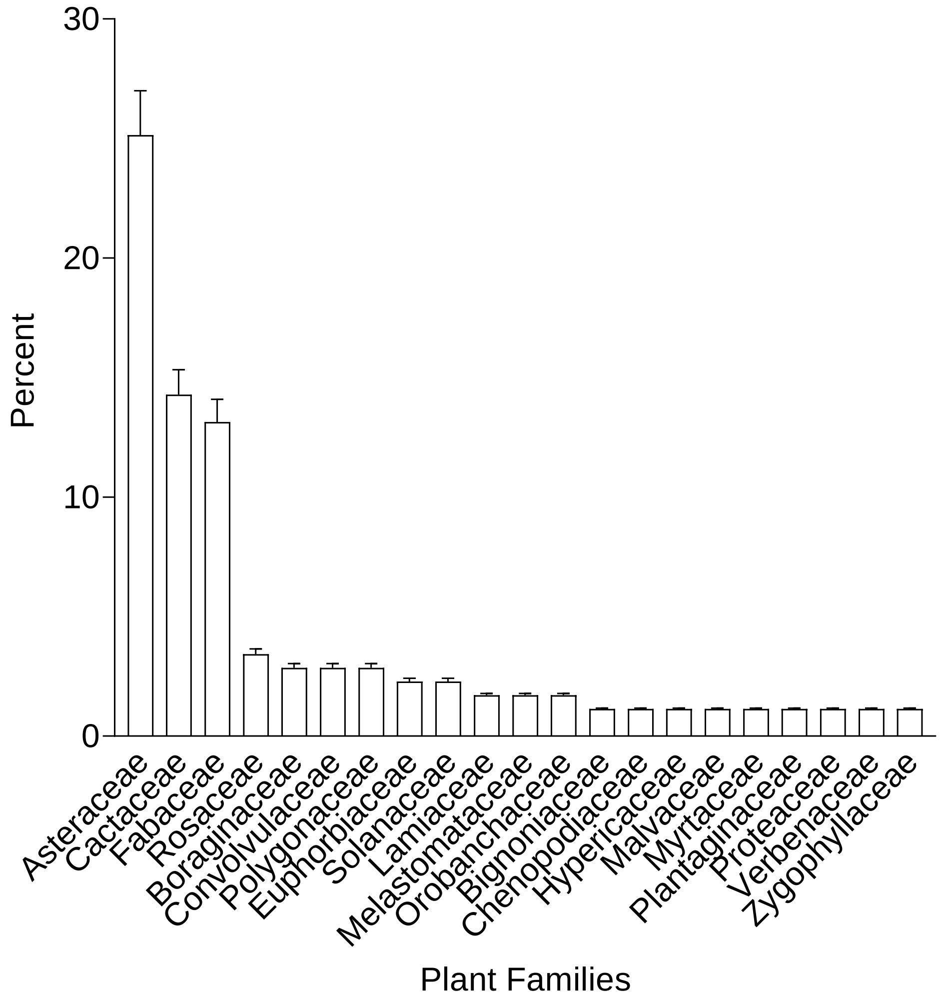


Fig. 2.3 Forest plots showing the odds of establishment of a species with regard to different biocontrol agent life history traits. Odds for each trait (proportion of success/proportion of failure) were calculated using predicted probabilities of successful establishment from logistic regression analysis (see Table 4 for values). The dotted vertical line represents equal probabilities of success and failure (odds = 1) as reference. Black circles are the mean odds for each trait and the horizontal lines indicate the confidence interval

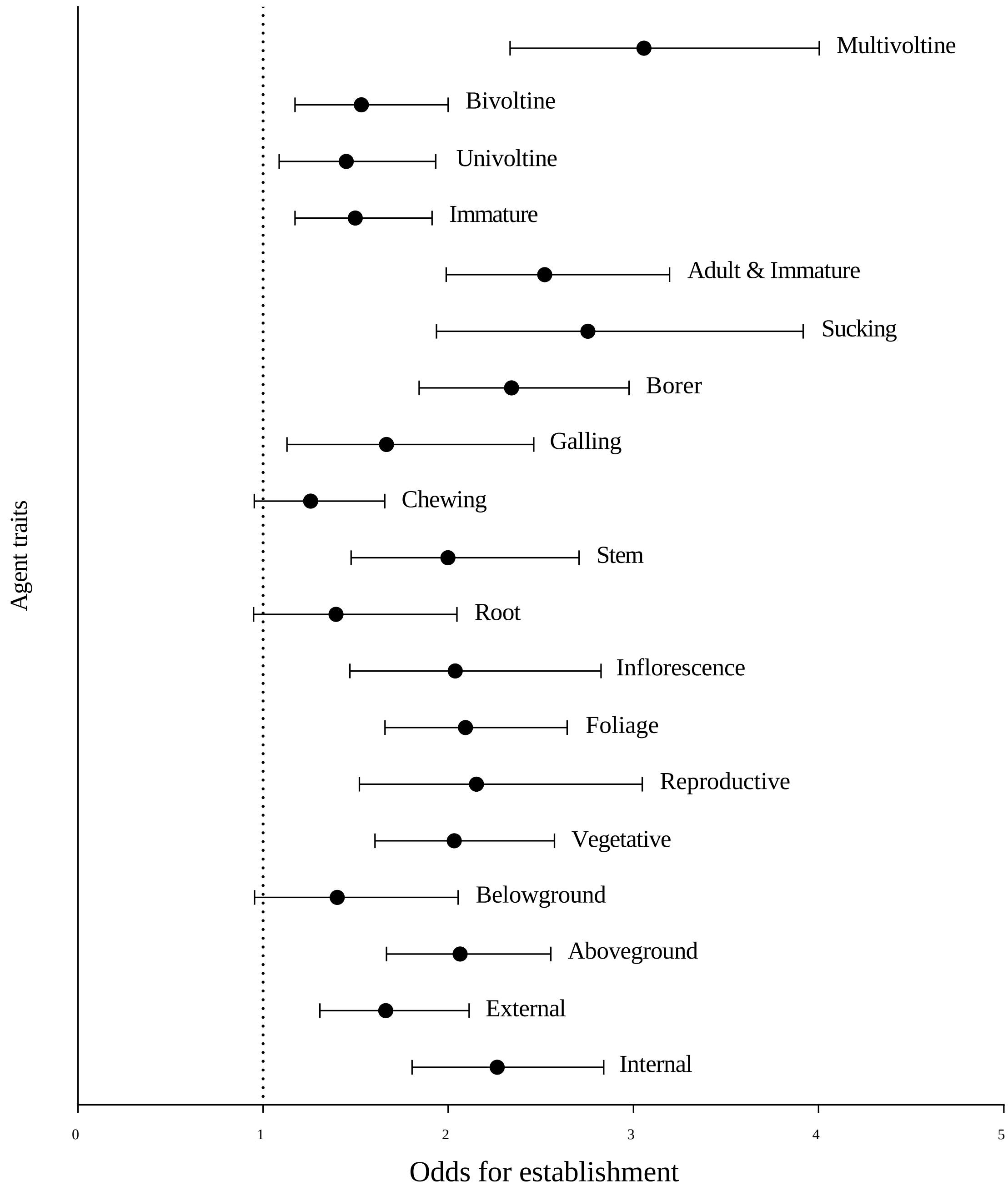


Fig. 2.4 Forest plots showing the odds of establishment for different target weed life history traits with 95% confidence interval. Odds for each trait (proportion of success/failure) were calculated using predicted probabilities of successful establishment from logistic regression analyses. The dotted vertical lines represent equal probabilities of success and failure (odds = 1). Black circles represent the mean odds for each trait and horizontal lines indicate the confidence interval

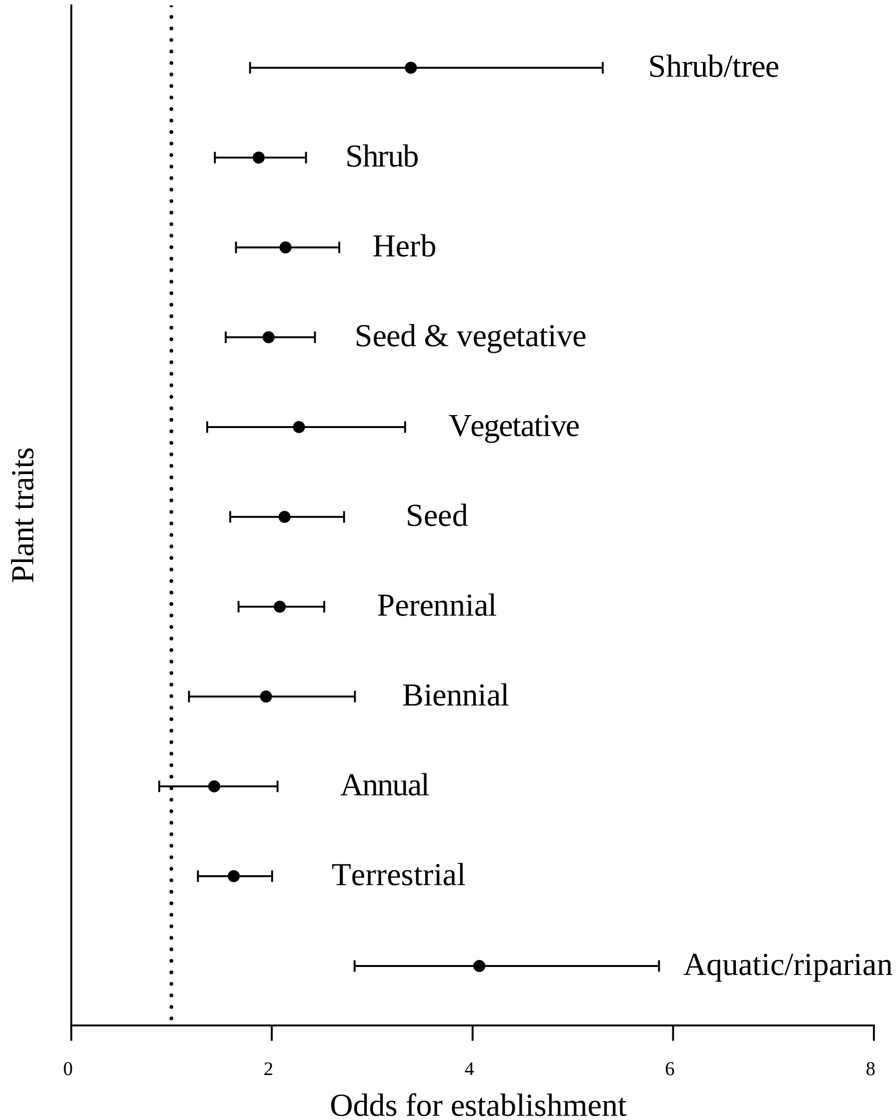


Fig. 2.5 Proportion of biocontrol agent releases associated with different biocontrol agent impact categories on target weed with regard agent life history traits. Proportions are based on total number of releases qualifying for that trait. The sum of proportions across the three impact categories therefore is 1. Error bars are Standard Errors

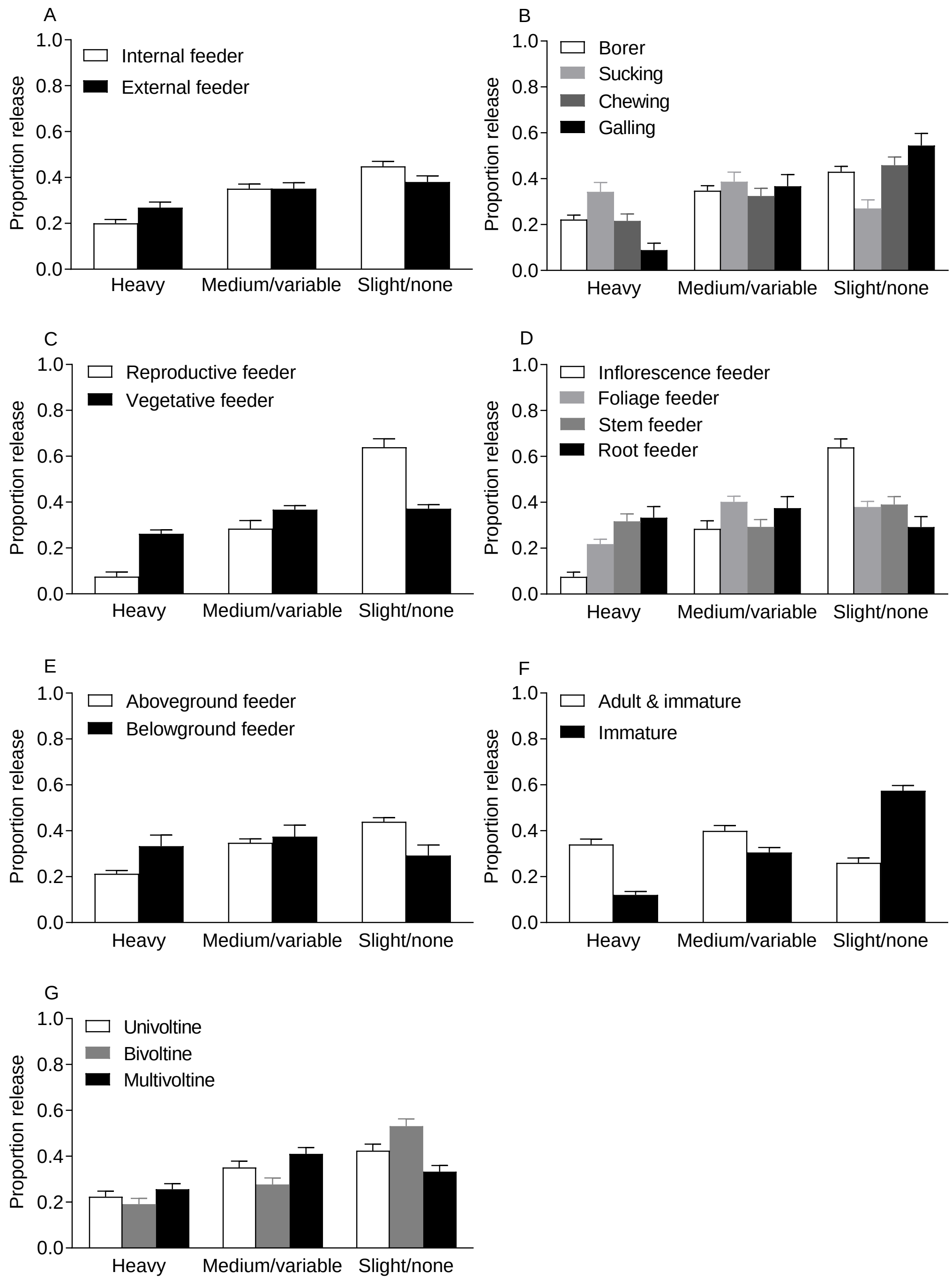
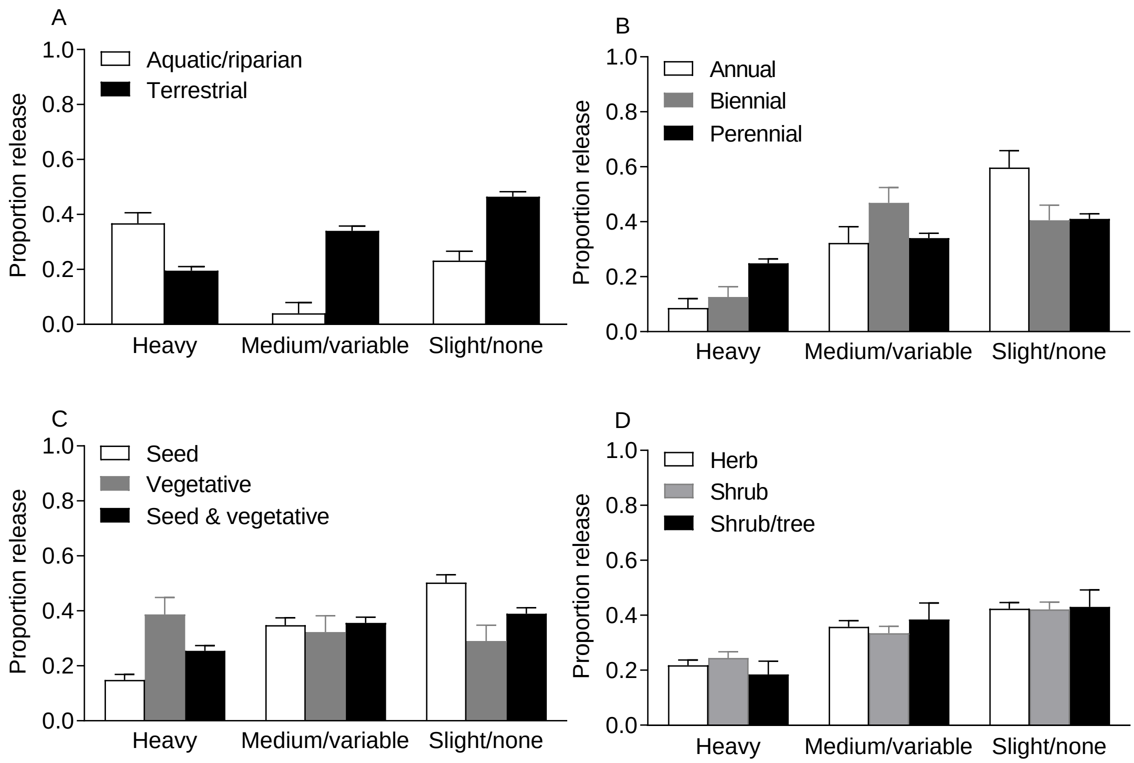


Fig. 2.6 Proportion of categorical biocontrol agent impact on target weed regard to target weed life history traits. Proportions are based on total number of releases qualifying for that trait. The sum of proportions across the three impact categories therefore is 1. Error bars are Standard Errors



Appendix A Biocontrol agent life history trait categories and levels used for this analysis

Life history traits	Levels	Definition
Feeding habits	Internal External	If agent's immature feeds on the target plant internally, regardless of the oviposition sites, are described as an internal feeder and the immatures feed on the plant externally, are external feeder
Feeding places	Aboveground Belowground	If immature feeds on aboveground plant parts are described as an aboveground feeder and agents feeding on plants belowground structures including roots and modified stem, for example rhizome, bulbs, tubers etc., are belowground feeders. Additionally, an agent that mines/bores through aboveground tissue and spent the majority of its life feeding on belowground parts is also grouped as a belowground feeder
Feeding parts	Vegetative Reproductive	An immature that feeds on vegetative plant parts, either above or belowground, is described as a vegetative. An immature feeding on plant reproductive parts (e. g. seed, flower, etc.) is assigned to the reproductive category
Feeding niches	Foliage, Stem, Root Inflorescence	Four categories were selected based on the agent primarily feeding plant parts and cause the most damage. If immatures feed on a leaf (e. g. leaf, petiole, vegetative buds, etc.), are called foliage feeder. Immatures feeding on stem (e. g. stem, branch, shoot, stem collar, or meristematic tip, etc.), are classified as a stem feeder. Similarly, immature that feds on roots including the rhizome, is root feeder. Immatures that feed on a plant's reproductive parts are grouped into inflorescence feeders
Feeding guilds	Borer, Chewing, Galling Sucking	An immature that bores into the plant parts and feeds internally, including miners, are grouped as borer. Immature that chews on the plant parts/ tissues externally are assigned to chewing group. If immatures cause galls on target weeds and feed inside the gall are grouped to galling category. Similarly, immature feeding by sucking plant sap is described as a sucking
Damaging stages	Immature & Adult/immature	If biocontrol agent's both adult and immature stages, inflict sufficient damages to target weed, they are categorized under adult/immature. If only immature caused significant damage to target wed, then they are grouped under immature

Life cycle	Univoltine, Bivoltine & Multivoltine	Agents with one generation, sometimes partial second generations per year, or agents requiring more than a year to complete a generation are assigned to univoltine group. Similarly, agents with two generations per year are classified as a bivoltine. Agents with more than two generations per year are grouped under the multivoltine category

The classification of each trait and its definition are based exclusively on immature's feeding, except damaging stage where adult damage was also considered

Appendix B Target weed life history and ecological traits selected for this study, their levels and definitions

Traits	Levels	Definition
Growth habit	Herb Shrub Shrub/ tree	Vascular plants that lack significant woody tissues above or at the ground- herbs Perennial, multi-segmented woody plants and typically have several stems arising from or near the ground- shrub Perennial woody plants with a single stem (trunk) and usually grow tall (>5 meters)- tree
Life cycle	Annual Biennial Perennial	A plant that completes its life cycle (from seed germination to seed production and then die off) in a single year is grouped as an annual A plant that usually completes its rosette stage in the first year and reproduces in its second year and dies off grouped as a biennial A plant that requires more than two years to complete its lifecycle is grouped as a perennial. Additionally, plant that resembles annual or biennial in aboveground growth but remains alive underground and regrowth following season is also classify as perennial. For example, rush skeleton weed
Ecosystem	Terrestrial Aquatic/riparian	Plants that grow and spend its entire lifecycle on the land mass is grouped as a terrestrial, and plants on water bodies and water-land interface are grouped under aquatic/riparian. Plant such as *Alternanthera* is classified as an aquatic/riparian species
Propagation	Seed Vegetative Seeds and vegetative	Plant reproducing using seeds, both sexually and apomictic seeds are ground under seeds, Plant reproducing exclusively by using vegetative propagules (stem and stem modification, root and root modification etc.) are vegetative, and Plant reproducing using both seeds and vegetative propagules are seeds and vegetative group.

Definition of growth habits are adopted from USDA-NRCS with some modifications

Reference

USDA-NRCS, 2021. https://plants.usda.gov/growth_habits_def.html.

Appendix C List of references used to collect information on life history traits of biological control agent

1 Adair, R. J., & Bruzzese, A. (2000). Evaluation and host specificity of two seed flies *Mesoclanis polana* and *M. magnipalpis* (Diptera: Tephritidae): biological control agents for *Chrysanthemoides monilifera* (Asteraceae) in Australia. *Bulletin of entomological research*, *90*(6), 467-474.

2 Adair, R. J., & Scott, J. K. (1989). The life-history and host specificity of *Comostolopsis germana* Prout (Lepidoptera: Geometridae), a biological control agent of *Chrysanthemoides monilifera* (Compositae). *Bulletin of Entomological Research*, *79*(4), 649-657.

3 Adair, R. J., & Scott, J. K. (1997). Distribution, life history and host specificity of *Chrysolina picturata* and *Chrysolina sp*. B (Coleoptera: Chrysomelidae), two biological control agents for *Chrysanthemoides monilifera* (Compositae). *Bulletin of Entomological Research*, *87*(4), 331-341.

4 Adair, R. J., & Scott, J. K. (1997). Distribution, life history and host specificity of *Chrysolina picturata* and *Chrysolina sp*. B (Coleoptera: Chrysomelidae), two biological control agents for *Chrysanthemoides monilifera* (Compositae). *Bulletin of Entomological Research*, *87*(4), 331-341.

5 Agius, J. (2017). *Lantanophaga pusillidactylus* (Walker, 1864) new to the Maltese Islands (Lepidoptera: Pterophoridae). *SHILAP Revista de Lepidopterología*, *45*(178), 259-261.

6 Aguirre, M. B., Diaz-Soltero, H., Claps, L. E., Saracho Bottero, A., Triapitsyn, S., Hasson, E., & Logarzo, G. A. (2016). Studies on the biology of *Hypogeococcus pungens* (sensu stricto) (Hemiptera: Pseudococcidae) in Argentina to aid the identification of the mealybug pest of Cactaceae in Puerto Rico. *Journal of Insect Science*, *16*(1), 58.

7 Anderson, D. M. (1974). Some species of *Smicronyx* (Coleoptera: Curculionidae) associated with Cuscuta species (Convolvulaceae) in Pakistan. In *Proceedings of the entomological society of Washington. Washington, 1974, 74(4), (pp:* 359-374).

8 Andreas, J.E., Winston, R. L., Coombs, E. M., Miller, T. W., Pitcairn, M. J., Randall, C. B., Turner, S., & Williams, W. (2017). Biology and biological control of scotch broom and gorse. USDA Forest Service, Forest Health Technology Enterprise Team, West Virginia.

9 Atlas of Living Australia (n.d). *Ategumia adipalis* (Lederer, 1863). https://bie.ala.org.au/species/urn:lsid:biodiversity.org.au:afd.taxon:0c267836-2507-4e82-8531-0e80643a3cfb.

10 Baars, J. R., Hill, M. P., Heystek, F., Neser, S., & Urban, A. J. (2007). Biology, oviposition preference and impact in quarantine of the petiole-galling weevil, *Coelocephalapion camarae* Kissinger, a promising candidate agent for biological control of *Lantana camara*. *Biological Control*, *40*(2), 187-195.

11 Baars, J. R., Urban, A. J., & Hill, M. P. (2003). Biology, host range, and risk assessment supporting release in Africa of *Falconia intermedia* (Heteroptera: Miridae), a new biocontrol agent for *Lantana camara*. *Biological Control*, *28*(3), 282-292.

12 Badenes-Perez, F. R., & Johnson, M. T. (2007). Ecology and impact of *Allorhogas sp*.(Hymenoptera: Braconidae) and *Apion sp*.(Coleoptera: Curculionoidea) on fruits of *Miconia calvescens* DC (Melastomataceae) in Brazil. *Biological Control*, *43*(3), 317-322.

13 Baker, C. R. B., Blackman, R. L., & Claridge, M. F. (1972). Studies on *Haltica carduorum* Guerin (Coleoptera: Chrysomelidae) an alien beetle released in Britain as a contribution to the biological control of creeping thistle, *Cirsium arvense* (L.) Scop. *Journal of Applied Ecology*, 9(3), 819-830.

14 Balciunas J., & Purcell M. (1991). Distribution and biology of a new Bagous weevil (Coleoptera: Curculionidae) which feeds on the aquatic weed, *Hydrilla verticillata*. *Australian Journal of Entomology*, 30, 333-338.

15 Baloch, G. M., Mohyuddin, A. I., & Ghani, M. A. (1967). Biological control of *Cuscuta spp*. II. Biology and host-plant range of *Melanagromyza cuscutae* Hering [Dipt. agromyzidae]. *Entomophaga*, *12*(4), 481-489.

16 Bamba, J. P., Miller, R. H., Reddy, G. V. P., & Muniappan, R. N. (2009). Studies on the biology, host specificity, and feeding behavior of *Acythopeus cocciniae* O'Brien and *Pakaluk* (Coleoptera: Curculionidae) on *Coccinia grandis* (L.) Voigt (Cucurbitaceae) and *Zehneria guamensis* (Merrill) Fosberg (Cucurbitaceae). *Micronesica*, *41*(1), 71-82.

17 Batra, S. W. T. (1979). Reproductive behavior of *Euaresta bella* and *E. festiva* (Diptera: Tephritidae), potential agents for the biological control of adventive North American ragweeds (*Ambrosia spp*.) in Eurasia. *Journal of the New York Entomological Society*, 87(2), 118-125.

18 Baudoin, A. B. A. M., Abad, R. G., Kok, L. T., & Bruckart, W. L. (1993). Field evaluation of *Puccinia carduorum* for biological control of musk thistle. *Biological control*, *3*(1), 53-60.

19 Berube, D. E. (1978). Larval descriptions and biology of *Tephritis dilacerata* [Dip.: Tephritidae], a candidate for the biocontrol of *Sonchus arvensis* in Canada. *Entomophaga*, *23*(1), 69-82.

20 Besaans, L. (2012). *Aceria lantanae* Lantana flower gall mite. https://www.arc.agric.za/arc-ppri/Fact%20Sheets%20Library/Aceria%20lantanae,%20the%20lantana%20flower%20gall%20mite.pdf.

21 Boldt, P. E. (1989). Biology and host specificity of *Trirhabda bacharidis* (Coleoptera: Chrysomelidae) on *Baccharis* (Asteraceae: Astereae). *Environmental entomology*, *18*(1), 78-84.

22 Boldt, P. E., & Campobasso, G. (1981). Biology of two weevils, *Ceutorhynchus trimaculatus* and *Trichosirocalus horridus*, on *Carduus spp*. in Europe. *Environmental Entomology*, *10*(5), 691-696.

23 Boldt, P. E., & Sobhian, R. (1993). Release and establishment of *Aceria malherbae* (Acari: Eriophyidae) for control of field bindweed in Texas. *Environmental Entomology*, *22*(1), 234-237.

24 Boldt, P. E., Cordo, H. A., & Gandolfo, D. (1991). Life history of *Stolas* (*Anacassis*) *fuscata* (Klug) (Coleoptera: Chrysomelidae) on seepwillow, *Baccharis salicifolia* (R.&P.) Pers. (Asteraceae). *Proceedings of the Entomological Society of Washington, 93,* 839-844.

25 Boughton, A. J., Wu, J., & Pemberton, R. W. (2007). Mating biology of *Austromusotima camptozonale* (Lepidoptera: Crambidae), a potential biological control agent of Old-World climbing fern, *Lygodium microphyllum* (Schizaeaceae). *Florida Entomologist*, 90(3), 509-517.

26 Bourchier, R. S., Erb, S., McClay, A. S., & Cassmann, A. (2001). *Euphorbia esula* (L.), Leafy Spurge, and *Euphorbia cyparissias* (L.), *Cypress Spurge* (Eupherbiaceae). *In* Mason, P. G., & Huber, J. T (Eds). (2001). Biological control programmes in Canada, 1981-2000. CABI Publishing.

27 Bourchier, R., Hansen, R., Lym, R., Norton, A., Olsen, D., Randall, C. B., Schwarzlander, M., & Skinner, L. (2006). Biology and Biological Control of Leafy Surface. USDA Forest Service, Forest Health Technology Entreprise Team.

28 Briano, J. A., Cordo, H. A., & Deloach, C. J. (2002). Biology and field observations of *Penthobruchus germaini* (Coleoptera: Bruchidae), a biological control agent for *Parkinsonia aculeata* (Caesalpiniaceae). *Biological Control*, *24*(3), 292-299.

29 Briese, D. T. (1986). Factors affecting the establishment and survival of *Anaitis efformata* (Lepidoptera: Geometridae) introduced into Australia for the biological control of St. John's Wort, *Hypericum perforatum*. II. field trials. *Journal of Applied Ecology*, 23(3), 821-839.

30 Briese, D. T. (1996). Life history of the *Onopordum capitulum* weevil *Larinus latus* (Coleoptera: Curculionidae). *Oecologia*, *105*(4), 454-463.

31 Briese, D. T. (1997). Biological control of St. John's wort: past, present and future. *Plant Protection Quarterly*, *12*, 73-80.

32 Briese, D. T. (2015). *Onopordium acanthium* L.- Scotch thistle, *Onopordium illyricum* L.- Illyrian thistle hybrids. Cullen, J., Julien, M., & McFadyen, R. (Eds.). (2012). Biological control of weeds in Australia. CSIRO Publishing.

33 Briese, D. T., Pettit, W. J., & Walker, A. (2004). Evaluation of the biological control agent, *Lixus cardui*, on Onopordum thistles: experimental studies on agent demography and impact. *Biological Control*, *31*(2), 165-171.

34 Briese, D. T., Pettit, W. J., Swirepik, A., & Walker, A. (2002). A strategy for the biological control of *Onopordum spp*. thistles in south-eastern Australia. *Biocontrol Science and Technology*, *12*(1), 121-136.

35 Briese, D. T., Sheppard, A. W., & Reifenberg, J. M. (1995). Open-field host-specificity testing for potential biological control agents of *Onopordum thistles*. *Biological Control*, *5*(2), 158-166.

36 Briese, D. T., Thomann, T., & Vitou, J. (2002). Impact of the rosette crown weevil *Trichosirocalus briesei* on the growth and reproduction of *Onopordum thistles*. *Journal of Applied Ecology*, *39*(4), 688-698.

37 Briese, D. T., & Zapater, M (2001). Biological control of Blue Heliotrope. Rural Industry Research and Development Corporation Publ. No. 01/119, RIRDC, Canberra, Australia.

38 Bruch, C. (1907). Metamorfósis y biologia de coleópteros argentinos. Hoffmann, J. H., & Moran, V. C. (1991). Biological control of *Sesbania punicea* (Fabaceae) in South Africa. Agriculture, ecosystems & environment, *37(1-3)*, 157-173.

39 Buccellato, L., Byrne, M. J., & Witkowski, E. T. F. (2012). Interactions between a stem gall fly and a leaf-spot pathogen in the biological control of *Ageratina adenophora*. *Biological Control*, *61*(3), 222-229.

40 Buckingham, G. R., & Bennett, C. A. (1994). Biological and Host Range Studies with *Bagous affinis*, An Indian Weevil that Destroys Hydrilla Tubers. Aquatic Plant Control Research Program, US Army Corps of Engineers.

41 Buckingham, G. R., & Okrah, E. A. (1993). Biological and host range studies with two species of Hydrellia (Diptera: Ephydridae) that feed on hydrilla. US Army Corps of Engineers.

42 Buckingham, G. R., Okrah, E. A., & Christian-Meier, M. (1991). Laboratory biology and host range of *Hydrellia balciunasi* [Diptera: Ephydridae]. *Entomophaga*, *36*(4), 575-586.

43 Bugbee, R. E., & Reigel, A. (1945). The Cactus Moth, *Melitara dentata* (Grote), and its effect on *Opuntia macrorrhiza* in western Kansas. *The American Midland Naturalist*, *33*(1), 117-127.

44 Burrows, N. J., Lukitsch, B. V., & Liberato, J. R. (2012). Rediscovery of the rust *Diabole cubensis*, released as a classical biological control agent against the invasive weed *Mimosa pigra* in Australia. *Australasian plant disease notes*, *7*(1), 171-175.

45 Cagnotti, C., Mc Kay, F., & Gandolfo, D. (2007). Biology and host specificity of *Plectonycha correntina* Lacordaire (Chrysomelidae), a candidate for the biological control of *Anredera cordifolia* (Tenore) Steenis (Basellaceae). *African Entomology*, *15*(2), 300-309.

46 Calvert, P. D., Wilson, S. W., & Tsai, J. H. (1987). *Stobaera concinna* (Homoptera: Delphacidae): Field Biology, laboratory rearing and descriptions of immature stages. *Journal of the New York Entomological Society, 95(1),* 91-98.

47 Caresche, L. A., & Wapshere, A. J. (1974). Biology and host specificity of the Chondrilla gall mite *Aceria chondrillae* (G. Can.)(Acarina, Eriophyidae). In Sobhian, R., & Andres, L. A. (1978). The response of the skeletonweed gall midge, *Cystiphora schmidti* (Diptera: Cecidomyiidae), and gall mite, *Aceria chondrillae* (Eriophyidae) to North American strains of rush skeletonweed (Chondrilla juncea). *Environmental Entomology, 7(4)*, 506-508.

48 Caresche, L. A., & Wapshere, A. J. (1974). Biology and host specificity of the Chondrilla gall mite *Aceria chondrillae* (G. Can.)(Acarina, Eriophyidae). *Bulletin of entomological research*, *64*(2), 183-192.

49 Caresche, L. A., & Wapshere, A. J. (1975). The Chondrilla gall midge, *Cystiphora schmidti* (Rübsaamen) (Diptera, Cecidomyiidae). II. biology and host specificity. *Bulletin of Entomological Research*, *65*(1), 55-64.

50 Casañas-Arango, A., Trujillo, E. E., de Hernandez, A. M., & Taniguchi, G. (1990). Field biology of *Cyanotricha necyria* Felder (Lep., Dioptidae), a pest of *Passiflora spp*., in southern Colombia's and Ecuador's Andean region. *Journal of Applied Entomology*, *109*(1-5), 93-97.

51 Center, T. D., Cuda, J. P., & Grodowitz, M. J. (2015). Aligatorweed flea bettle, *Agasicles hygrophila* Selman & Vogt (Coleoptera:Chrysomelidae: Halticinae). Featured creatures. Universiy of Florida, IFAS.

http://entnemdept.ufl.edu/creatures/beneficial/beetles/alligatorweed_flea_beetle.htm.

52 Cillers, C (n. d). Salvina weevil (*Cyrtobagous salviniae*), a natural enemy of Salvinia (Salvinia molesta), a freefloating fern, in South Africa. In Dossiers on biological control agents available to aid alien plant control. Plant protection institute, South Africa. https://www.arc.agric.za/arc-ppri/Leaflets%20Library/Cyrtobagous%20salviniae.pdf.

53 Cilliers, C. J. (1999). *Lysathian. sp*.(Coleoptera: Chrysomelidae), a host-specific beetle for the control of the aquatic weed *Myriophyllum aquaticum* (Haloragaceae) in South Africa. *Hydrobiologia*, *415*, 271-276.

54 Cock, M. J. W. (1982). The biology and host specificity of *Liothrips mikaniae* (Priesner)(Thysanoptera: Phlaeothripidae), a potential biological control agent of *Mikania micrantha* (Compositae). *Bulletin of Entomological Research*, *72*(3), 523-533.

55 Coetzer, W. (2000). Oviposition preference of *Sulcobruchus subsuturalis* (Pic)(Coleoptera: Bruchidae), an introduced natural enemy of *Caesalpinia decapetala* (Roth) Alston (Caesalpiniaceae) in South Africa. *African entomology*, *8*(2), 293-297.

56 Colpetzer, K., Hough-Goldstein, J., Harkins, K. R., & Smith, M. T. (2004). Feeding and oviposition behavior of *Rhinoncomimus latipes* Korotyaev (Coleoptera: Curculionidae) and its predicted effectiveness as a biological control agent for *Polygonum perfoliatum* L.(Polygonales: Polygonaceae). *Environmental Entomology*, *33*(4), 990-996.

57 Compton, J. A. F. (1988). Potential for the biological control of *Echium plantagineum* L. (Boraginaceae) with flower-eating insects, with special reference Heer (Col.: Nitidulidae). M. S. Thesis, Imperial College of Science and Technology, University of London.

58 Cook, W. (2016). An account of the life history of *Liothrips urichi*, Karny, A thrips attacking *Clidemia hirta* D. Don in Trinidad, Dissertation.

59 Cordo, H. A., DeLoach, C. J., & Ferrer, M. (1984). Biology and larval host range of the flea beetle *Disonycha argentinensis* (Coleoptera: Chrysomelidae) on alligatorweed in Argentina. *Annals of the Entomological Society of America*, *77*(2), 134-141.

60 Craemer, C., Sobhian, R., McClay, A. S., & Amrine Jr, J. W. (1999). A new species of *Cecidophyes* (Acari: Eriophyidae) from *Galium aparine* (Rubiaceae) with notes on its biology and potential as a biological control agent for *Galium spurium*. *International Journal of Acarology*, *25*(4), 255-263.

61 Cruttwell, R. E. (1973). Insects attacking *Eupatorium odoratum* in the neotropics. 2. Studies of the seed weevil *Apion brunneonigrum* BB, and its potential use to control *Eupatorium odoratum* L. *Technical Bulletin of the Commonwealth Institute of Biological Control*, *16*, 117-124.

62 Cruttwell, R. E. (1977). Insects and mites attacking *Eupatorium odoratum* L. in the Neotropics. 5. *Mescinia sp*. nr. *parvula* (Zeller). *Technical Bulletin, Commonwealth Institute of Biological Control*, (18), 49-58.

63 Davies, K. A., & Giblin-Davis, R. M. (2004). The biology and associations of *Fergusobia* (Nematoda) from the *Melaleuca leucadendra*-complex in eastern Australia. *Invertebrate Systematics*, *18(3)*, 291-319.

64 Davis, D. R., Kassulke, R. C., Harley, K. L., & Gillett, J. D. (1991). Systematics, morphology, biology, and host specificity of *Neurostrota gunniella* (Busck)(Lepidoptera: Gracillariidae), an agent for the biological control of *Mimosa pigra* L. In Smith , C. S., & Wilson, C. G. (1995). Close to the edge: microhabitat selection by *Neurostrota gunniella* (Busck)(Lepidoptera: Gracillariidae), a biological control agent for *Mimosa pigra* L. in Australia. *Australian Journal of Entomology*, *34(3)*, 177-180.

65 Day, M. D., & McAndrew, T. D. (2003). The biology and host range of *Falconia intermedia* (Hemiptera: Miridae), a potential biological control agent for *Lantana camara* (Verbenaceae) in Australia. *Biocontrol Science and Technology*, *13*(1), 13-22.

66 Day, M. D., Wiley, C. J., Playford, J., & Zalucki, M. P. (2003). Lantana: current management status and future prospects- Part II, (No. 435-2016-33733). Australian Center for International Agriculture Research Canberra, Australian Government, ACIAR monograph, 102.

67 Day, M. D., Wilson, B. W., & Nahrung, H. F. (1999). The life history and host range of *Charidotis pygmaea* (Col.: Chrysomelidae), a biological control agent for *Lantana montevidensis* (Verbenaceae). *Biocontrol science and technology*, *9*(3), 347-354.

68 DeLoach, C. J., & Cordo, H. A. (1976). Life cycle and biology of *Neochetina bruchi*, a weevil attacking waterhyacinth in Argentina, with notes on *N. eichhorniae*. *Annals of the Entomological Society of America*, *69*(4), 643-652.

69 DeLoach, C. J., & Cordo, H. A. (1978). Life history and ecology of the moth *Sameodes albiguttalis*, a candidate for biological control of waterhyacinth. *Environmental Entomology*, *7*(2), 309-321.

70 DeLoach, C. J., DeLoach, A. D., & Cordo, H. A. (1976). *Neohydronomus pulchellus*, a weevil attacking *Pistia stratiotes* in South America: biology and host specificity. *Annals of the Entomological Society of America*, *69*(5), 830-834.

71 Dempster, J. P. (1982). The ecology of the cinnabar moth, *Tyria jacobaeae* L. (Lepidoptera: Arctiidae). In *Advances in Ecological Research, 12,* 1-36.

72 Department of Agriculture, Fisheries and Forestry (2013). *Crocidosema lantana*. https://www.daf.qld.gov.au/__data/assets/pdf_file/0005/71636/IPA-Lantana-Biocontrol-11.pdf.

73 Department of Agriculture, Fisheries and Forestry (2013). *Salbia haemorrhoidalis*. https://www.daf.qld.gov.au/__data/assets/pdf_file/0007/69154/IPA-Lantana-Biocontrol-7.pdf.

74 Department of Agriculture, Fisheries and Forestry Biosecurity (2013). *Octotoma championi*. https://www.daf.qld.gov.au/__data/assets/pdf_file/0004/62860/IPA-Lantana-Biocontrol-12.pdf.

75 Department of Agriculture, Fisheries and Forestry Biosecurity (2013). *Ophiomyia lantanae*. https://www.daf.qld.gov.au/__data/assets/pdf_file/0003/62904/IPA-Lantana-Biocontrol-4.pdf.

76 Dhileepan, K., Bayliss, D., & Treviño, M. (2010). Thermal tolerance and potential distribution of *Carvalhotingis visenda* (Hemiptera: Tingidae), a biological control agent for cat's claw creeper, *Macfadyena unguis-cati* (Bignoniaceae). *Bulletin of entomological research*, *100*(2), 159-166.

77 Dhileepan, K., Snow, E. L., Rafter, M. A., Treviño, M., McCarthy, J., & Wilmot Senaratne, K. A. D. (2007). The leaf-tying moth *Hypocosmia pyrochroma* (Lep., Pyralidae), a host-specific biological control agent for cat's claw creeper *Macfadyena unguis-cati* (Bignoniaceae) in Australia. *Journal of Applied Entomology*, *131(8)*, 564-568.

78 Dhileepan, K., Taylor, D. B., Lockett, C., & Treviño, M. (2013). Cat's claw creeper leaf-mining jewel beetle *Hylaeogena jureceki* Obenberger (Coleoptera: Buprestidae), a host-specific biological control agent for *Dolichandra unguis-cati* (Bignoniaceae) in Australia. *Australian Journal of Entomology*, *52(2)*, 175-181.

79 Dhileepan, K., Trevino, M., & Snow, L. (2006). Application to release the leaf-sucking bug *Carvalhotingis visenda* (Hemiptera: Tingidae), a potential biological control agent for cat's claw creeper *Macfadyena unguis-cati* (Bignoniaceae). Alan Fletcher Research Station, Queensland Department of Natural Resources, Mines and Water, Brisbane, 26.

80 Dhileepan, K., Trevino, M., Vitelli, M. P., Wilmot Senaratne, K. A. D., McClay, A. S., & McFadyen, R. E. (2012). Introduction, establishment, and potential geographic range of *Carmenta* sp. nr *ithacae* (Lepidoptera: Sesiidae), a biological control agent for *Parthenium hysterophorus* (Asteraceae) in Australia. *Environmental entomology*, *41*(2), 317-325.

81 Diatloff, G., & Palmer, W. A. (1988). The host specificity and biology of *Aristotelia ivae* Busck (Gelechiidae) and *Lorita baccharivora* Pogue (Tortricidae), two microlepidoptera selected as biological control agents for *Baccharis halimifolia* (Asteraceae) in Australia. *Proceedings of the Entomological Society of Washington*, *90*(4), 458-461.

82 Diaz, R., Overholt, W. A., & Hibbard, K. (2013). Air Potato Leaf Beetle (Suggested Common Name), *Lilioceris cheni* Gressitt and Kimoto (Insecta: Coleoptera: Chrysomelidae: Criocerinae): EENY547/IN972, 1/2013. *EDIS*, *2013*(1).

83 Diez-Rodríguez, G. I., Nava, D. E., Hubner, L. K., Canez Neto, F. C., & Antunes, L. E. C. (2016). Biology and infestation of *Strepsicrates smithiana* in strawberry guava. *Pesquisa Agropecuária Brasileira*, *51*(3), 280-283.

84 Dodd, A. P. (1940). The biological campaign against prickly pear. Zimmermann, H. G., Moran, V. C., & Hoffmann, J. H. (2001). The renowned cactus moth, *Cactoblastis cactorum* (Lepidoptera: Pyralidae): its natural history and threat to native *Opuntia* floras in Mexico and the United States of America. *Florida Entomologist*, 543-551.

85 Donnelly, D. (1992). Entomology of the potential host range of three seed-feeding *Melanterius spp.*(Curculionidae), candidate for the biological control of

Australian *Acacia spp*. and *Paraserianthes* (Albizia) *lophantha* in South Africa. *Phytophylactica*, *24*(2), 163-168.

86 Dorchin, N., & Adair, R. J. (2011). Two new Dasineura species (Diptera: Cecidomyiidae) from coastal tea tree, *Leptospermum laevigatum* (Myrtaceae) in Australia. *Australian Journal of Entomology, 50*(1), 65-71.

87 Dunn, P. H., & Rizza, A. (1976). Bionomics of *Psylliodes chalcomera*, a candidate for biological control of musk thistle. *Annals of the Entomological Society of America*, *69*(3), 395-398.

88 Evans, K. J., & Bruzzese, E. (2003). Life history of *Phragmidium violaceum* in relation to its effectiveness as a biological control agent of European blackberry. *Australasian Plant Pathology*, *32*(2), 231-239.

89 Firehun, Y., Struik, P. C., Lantinga, E. A., & Taye, T. (2015). Adaptability of two weevils (*Neochetina bruchi* and *Neochetina eichhorniae*) with potential to control water hyacinth in the Rift Valley of Ethiopia. *Crop Protection*, *76*, 75-82.

90 Flanders, R. (2007). Field Release of *Neomusotima conspurcatalis* (Warren) (Lepidoptera: Crambidae), an insect for biological control of Old-World Climbing Fern (*Lygodium microphyllum*), in the Continental United States. Environmental Assessment. U. S. Department of Agriculture, Animal and plant health inspection service.

91 Fornasari, L. (1993). Life History of the Flea Beetle, *Aphthona abdominalis* Duftschmid, on *Euphorbia esula* L (Leafy Spurge) in Italy. *Biological Control*, *3*(3), 161-175.

92 Fornasari, L., & Sobhian, R. (1993). Life history of *Eustenopus villosus* (Coleoptera: Curculionidae), a promising biological control agent for yellow starthistle. *Environmental entomology*, *22*(3), 684-692.

93 Forno, I. W., Kassulke, R. C., & Day, M. D. (1991). Life cycle and host testing procedures for *Carmenta mimosa* Eichlin and Passoa (Lepidoptera: Sesiidae), a biological control agent for *Mimosa pigra* L.(Mimosaceae) in Australia. *Biological Control*, *1*(4), 309-315.

94 Forno, I. W., Kassulke, R. C., & Harley, K. L. S. (1992). Host specificity and aspects of the biology of *Calligrapha pantherina* (Col.: Chrysomelidae), a biological control agent of *Sida acuta* [Malvaceae] and *S. rhombifolia* in Australia. *Entomophaga*, 37(3), 409-417.

95 Forno, W., Heard, T. A., & Day, M. D. (1994). Host specificity and aspects of the biology of *Coelocephalapion aculeatum* (Coleoptera: Apionidae), a potential biological control agent of *Mimosa pigra* (Mimosaceae). *Environmental entomology*, *23*(1), 147-153.

96 Fowler, S. (2016). Tradescantia leaf beetle *(Neolema oglonlini*). https://www.landcareresearch.co.nz/__data/assets/pdf_file/0013/20506/Tradescantia_Leaf_-Beetle.pdf.

97 Fowler, S., Gianotti, A., Hill, R., Killgore, E., Morin, L., Sugiyama, L., & Winks, C. (1999). Biological control of mist flower (*Ageratina riparia*, Asteraceae) in New Zealand. In O'Callaghan M (ed). 52nd *Proceedings of the New Zealand Plant Protection Conference.* The New Zealand Plant Protection Society Inc, Auckland, pp 6–11.

98 Freese, G., & Zwölfer, H. (1996). The problem of optimal clutch size in a tritrophic system: the oviposition strategy of the thistle gallfly *Urophora cardui* (Diptera, Tephritidae). *Oecologia*, *108*(2), 293-302.

99 Frick, K. E. (1971). *Longitarsus jacobaeae* (Coleoptera: Chrysomelidae), a flea beetle for the biological control of tansy ragwort. II. Life history of a Swiss biotype. *Annals of the Entomological Society of America*, *64*(4), 834-840.

100 Fyfe, R.V. (1937). The lantana bug, *Teleonemia lantanae* Distant. Simelane, D. O. (2006). Effect of herbivory by *Teleonemia scrupulosa* on the performance of *Longitarsus bethae* on their shared host, *Lantana camara*. *Biological Control*, *39*(3), 385-391.

101 Gandolfo, D. A. N. I. E. L., Sudbrink, D., & Medal, J. U. L. I. O. (1999). Biology and host specificity of the tortoise beetle Gratiana boliviana, a candidate for biocontrol of tropical soda apple (*Solanum viarum*). In Spencer, N. R. (ed). *Proceedings of the X International Symposium on Biological Control of Weeds*, Montana State University, Bozeman, Montana, USA, pp. 697.

102 Gandolfo, D., Mckay, F., Medal, J. C., & Cuda, J. P. (2007). Open-field host specificity test of *Gratiana boliviana* (Coleoptera: Chrysomelidae), a biological control agent of tropical soda apple (Solanaceae) in the United States. *Florida Entomologist*, *90*(1), 223-228.

103 Ganga Visalakshy, P. N. G. and Jayanth, K. P. (1991). Studies on the life history and development of *Orthogalumna terebrantis* Wallwork, an exotic oribatid of *Eichhornia crassipes*. *Entomon*, *16*(1), 53-57.

104 Gardner, D. E. (1999). *Septoria hodgesii* sp. nov.: a potential biocontrol agent for *Myrica faya* in Hawaii. *Mycotaxon*, *70*, 247-253.

105 Gareeb, M., & Zachariades, C. (2003). *Calycomyza eupatorivora*, a new agent for biological control of *Chromoleana odorata* in South Africa. In *Proc S Afr Sug Technol Ass.*, pp. 622-623

106 Gassmann, A. (1987). Investigations on the *Pegomya argyrocephala* complex of species (Diptera: Anthomyiidae) to select candidate biological control agents for leafy and cypress spurge in North America. In Gassmann, A., & Shorthouse, J. D. (1990). Structural damage and gall induction by *Pegomya curticornis* and *Pegomya euphorbiae* (Diptera: Anthomyiidae) within the stems of leafy spurge (*Euphorbia× pseudovirgata*) (Euphorbiaceae). *The Canadian Entomologist*, *122*(3), 429-439.

107 Gassmann, A. (1994). *Chamaesphecia crassicornis* Bartel 1912 (Lepidopterea; Sesiidae), a suitable agent for the biological control of leafy spurge (*Euphorbia esula* L.)(Euphorbiaceae) in North America. Final report, CABI.

108 Gassmann, A., & Tosevski, I. (1994). Biology and host specificity of *Chamaesphecia hungarica* and *Ch. astatiformis* (Lep.: Sesiidae) two candidates for the biological control of leafy spurge, *Euphorbia esula* (Euphorbiaceae) in North America. *Entomophaga*, *39*(2), 237-245.

109 Gassmann, A., Schroeder, D., Maw, E., & Sommer, G. (1996). Biology, Ecology, and Host Specificity of European *Aphthona spp*.(Coleoptera, Chrysomelidae) used as biocontrol agents for Leafy Spurge, *Euphorbia esula* (Euphorbiaceae), in North America. *Biological control*, *6*(1), 105-113.

110 Gerber, E., Schaffner, U., Gassmann, A., Hinz, H. L., Seier, M., & Müller-Schärer, H. (2011). Prospects for biological control of *Ambrosia artemisiifolia* in Europe: learning from the past. *Weed Research*, *51*(6), 559-573.

111 Giblin-Davis, R. M., Makinson, J., Center, B. J., Davies, K. A., Purcell, M., Taylor, G. S., ... & Center, T. D. (2001). *Fergusobia/Fergusonina*-induced shoot bud gall development on *Melaleuca quinquenervia*. *Journal of Nematology*, 33(4), 239.

112 Gillespie, D & Bsaans, L. (2014). *Anthonomus santacruzi*, A glowerbud-feeding weevils released for biocontrol of bugweed. http://www.arc.agric.za/arc-ppri/Fact%20Sheets%20Library/Anthonomus%20santacruzi.pdf.

113 Gilreath, M. E., & Smith Jr, J. W. (1987). Bionomics of *Dactylopius confusus* (Homoptera: Dactylopiidae). *Annals of the Entomological Society of America*, *80*(6), 768-774.

114 Global Invasive Species Database. (2020). Species profile: *Cactoblastis cactorum.* http://www.iucngisd.org/gisd/species.php?sc=729.

115 Goolsby, J. A., & Moran, P. (2009). Host range of *Tetramesa romana* Walker (Hymenoptera: Eurytomidae), a potential biological control of giant reed, *Arundo donax* L. in North America. *Biological Control*, *49*(2), 160-168.

116 Gordon, A. J. (1999). A review of established and new insect agents for the biological control of *Hakea sericea* Schrader (Proteaceae) in South Africa. *African Entomology Memoir*, *1*, 35-43.

117 Gordon, A. J. (2011). Biological control endeavours against Australian myrtle, *Leptospermum laevigatum* (Gaertn.) F. Muell.(Myrtaceae), in South Africa. *African Entomology*, *19*(1), 349-355.

118 Gourlay, H. (2007). Grose spider mite (*Tetranychus lintearius*). https://www.landcareresearch.co.nz/__data/assets/pdf_file/0017/20474/Gorse_Spider_Mite.pdf.

119 Gourlay, H. (2010). Broom leaf beetle (*Gonioctena olivacea)*. https://www.landcareresearch.co.nz/__data/assets/pdf_file/0015/20562/Broom_leaf_beetle.pdf.

120 Gourlay, H. (2011). Ragwort plume moth (*Platyptilia isodactyla*). https://www.landcareresearch.co.nz/__data/assets/pdf_file/0013/20533/Ragwort_Plume_Moth.pdf.

121 Gratton, C., & Welter, S. C. (1998). Oviposition preference and larval performance of *Liriomyza helianthi* (Diptera: Agromyzidae) on normal and novel host plants. *Environmental Entomology*, *27*(4), 926-935.

122 Großkopf, G. (2006). Investigations on three species of Diptera associated with hawkweeds in Europe and their potential for biological control of alien invasive Hieracium spp. New Zealand and North America. Dissertation, Christian-Albrechts-Universität, Kiel, Germany.

123 Gültekin, L., Güçlü, S., & Nikulina, O. N. (2003). The life history of the capitulum weevil, *Larinus latus* (Herbst)(Coleoptera, Curculionidae). *New Zeland Journal of Agriculture Research, 46,* 271-274.

124 Gunn, B. (1978). Research notes on *Dicomada rufa*. Kluge, R. J., & Gordon, A. J. (2004). The fixed plot survey method for determining the host range of the

flowerbud-feeding weevil *Dicomada rufa*, a candidate for the biological control of Hakea sericea in South Africa. *BioControl, 49*(3), 341-355.

125 Gutierrez, J., & Forno, I. W. (1989). Introduction into New Caledonia of two hispine phytophages of lantana: *Octotoma scabripennis* and *Uroplata girardi* (Coleoptera, Chrysomelidae). Acta oecologica. *Oecologia applicata*, 10(1), 19-29.

126 Hakizimana, S., & Olckers, T. (2013). Should the flower bud weevil *Anthonomus santacruzi* (Coleoptera: Curculionidae) be considered for release against the invasive tree *Solanum mauritianum* (Solanaceae) in New Zealand?. *Biocontrol science and technology*, *23*(2), 197-210.

127 Hapai, M. N., & Chang, F. (1986). The Induction of Gall Formation in *Ageratina riparia* by *Procecidochares alani* (Diptera: Tephritidae). I. Gall Histology and Internal Gross Morphology of the Third Instar. *Proceedings of Hawaiian Entomologial Society*, 26: 59-64.

128 Harley, K. L. S. (1969). Assessment of the suitablity of *Plagihammus spinipennis* (Thoms.)(Col., Cerambycidae) as an agent for control of weeds of the genus *Lantana* (Verbenaceae). I. Life-history and capacity to damage *L. camara* in Hawaii. *Bulletin of Entomological Research*, *58*(3), 567-574.

129 Harley, K. L. S. (1969). The suitability of Octotoma scabripennis Guér. and Uroplata girardi Pic (Col., Chrysomelidae) for the control of Lantana (Verbenaceae) in Australia. In Gutierrez, J., & Forno, I. W. (1989). Introduction into New Caledonia of two hispine phytophages of lantana: *Octotoma scabripennis* and *Uroplata girardi* (Coleoptera, Chrysomelidae). Acta oecologica. Oecologia applicata, 10(1), 19-29.

130 Harley, K. L. S., & Kassulke, R. C. (1974). The suitability of *Phytobza lantanae* Frick for biological control of *Lantana camera* in Australia. *Australian Journal of Entomology*, *13*(3), 229-233.

131 Harley, K. L. S., & Kassulke, R. C. (1975). *Apion antiquum* (Curculionoidea: Apionidae) for biological control of the weed *Emex australis*. *Australian Journal of Entomology*, *14*(3), 271-276.

132 Harris, P. (1964). Host specificity of *Altica carduorum* Guer.(Coleoptera: Chrysomelidae). *Canadian Journal of Zoology*, *42*(5), 857-862.

133 Hasan, S., & Aracil, E. (1991). Biology and effectiveness of *Uromyces heliotropii* Sred., a potential biological control agent of *Heliotropium europaeum* L. *New Phytologist*, *118*(4), 559-563.

134 Hasan, S., & Wapshere, A. J. (1973). The biology of *Puccinia chondrillina* a potential biological control agent of skeleton weed. *Annals of Applied Biology*, *74*(3), 325-332.

135 Haseler, W. H. (1965). Life-history and behaviour of the crofton weed gall fly *Procedidochares utilis* Stone (Diptera: Trypetidae). *Australian Journal of Entomology*, *4*(1), 27-32.

136 Heard, T. A., Burcher, J. A., & Forno, I. W. (1999). *Chalcodermus serripes* (Coleoptera: Curculionidae) for Biological Control of *Mimosa pigra*: host relations and life cycle. *Biological Control*, *15*(1), 1-9.

137 Heard, T. A., Mira, A., Fichera, G., & Segura, R. (2012). *Nesaecrepida infuscata*: a biological control agent of the invasive plant *Mimosa pigra*. *BioControl*, *57*(4), 573-580.

138 Heystek, F., & Baars, J. R. (2005). Biology and host range of *Aconophora compressa*, a candidate considered as a biocontrol agent of *Lantana camara* in Africa. *BioControl*, *50*(2), 359-373.

139 Hill, M. P. (1998). Life history and laboratory host range of *Stenopelmus rufinasus*, a natural enemy for *Azolla filiculoides* in South Africa. *BioControl*, *43*(2), 215-224.

140 Hill, M. P., & Oberholzer, I. G. (2000). Host specificity of the grasshopper, *Cornops aquaticum*, a natural enemy of water hyacinth. In Spencer, N. R (ed). *Proceedings of the 10th International Symposium on Biological Control of Weeds,* Montana State University, Bozeman, Montana, USA, pp. 349-356.

141 Hill, R. (2019). Importation and release of two beetles, *Lema basicostata* and N*eolema abbreviata*, as biological control agents for the weed tradescantia. An application to the Environmental Protection Authority for permission to release two beetles, *Lema basicostata* and *Neolema abbreviata* into New Zealand as a biological control agents for the weed *Tradescantia fluminensis.*

142 Hill, R. L., & Gourlay, A. H. (2002). Host-range testing, introduction, and establishment of *Cydia succedana* (Lepidoptera: Tortricidae) for biological control of gorse, *Ulex europaeus* L., in New Zealand. *Biological Control*, *25*(2), 173-186.

143 Hill, R. L., Gourlay, A. H., & Fowler, S. V. (2000). The biological control program against gorse in New Zealand. In Spencer, N. R. (ed). *Proceedings of the X international Symposium on Biological Control of Weeds*, Montana State University Bozeman, Montana, USA, pp. 909-917.

144 Hinz, H. L. (1998). Life history and host specificity of *Rhopalomyia* n. sp.(Diptera: Cecidomyiidae), a potential biological control agent of scentless chamomile. *Environmental Entomology*, *27*(6), 1537-1547.

145 Hoffmann, J. H., & Moran, V. C. (1999). A review of the agents and factors that have contributed to the successful biological control of *Sesbania punicea* (Cav.) Benth.(Papilionaceae) in South Africa. *Biological Control of Weeds in South Africa. African Entomology Memoir*, *1*, 75-79.

146 Hoffmann, J. H., Impson, F. A. C., & Moran, V. C. (1993) Competitive Interactions between Two Bruchid Species (*Algarobius* spp) Introduced into South Africa for Biological Control of Mesquite Weeds (*Prosopis spp*). *Biological Control*, *3,* 215-220.

147 Huber, J. T. (1981). Observations on the heliotrope flea beetle, *Longitarsus albineus* [Col.: Chrysomelidae] with tests of its host specificity. *Entomophaga*, *26*(3), 265-273.

148 Ibrahim, G. (2003). Studies on biology of Cyperus bulb borer, *Athesapeuta cyperi* Marshall and biosuppression of *Cyperus rotundus* Linnaeus. Dissertation, Mahatma Phule Krishi Vidaypeeth, Rahuri.

149 Ireson, J. (2008). Biological control of selender and nooding thistle: Crown weevil. Weeb biological control pamphlet. Tasmanian Institute of Agriculture Research. *Research information Bulletin. http://www.southeastweeds.org.au/system/files//f12/o838/SLENDER-AND-NODDING-THISTLES-CROWN-WEEVIL.pdf*.

150 Ireson, J. E., Gourlay, A. H., Sagliocco, J. L., Holloway, R. J., Chatterton, W. S., & Corkrey, R. (2013). Host testing, establishment and biology of the gorse soft shoot moth, *Agonopterix umbellana* (Fabricius)(Lepidoptera: Oecophoridae), a potential biological control agent for gorse, *Ulex europaeus* L.(Fabaceae), in Australia. *Biological control*, *67*(3), 451-461.

151 Jackson, J. J. (1997). Biology of *Aphthona nigriscutis* (Coleoptera: Chrysomelidae) in the laboratory. *Annals of the Entomological Society of America*, *90*(4), 433-437.

152 Johnson, R. S. (2008). Field release of *Aulacidea acroptilonica* (Hymenoptera:Cynipidae), an insect for biological control of russian knapweed (*Acroptilon repens),* in the cotinental United States. Environmental assessment, Unites States Department of Agriculture, Animal and Plant Health Inspection Service. https://www.aphis.usda.gov/plant_health/ea/downloads/aulacidea%20_acroptilonica.pdf.

153 Johnson, R. S. (2008). Field Release of the Biological Control Agent *Lophodiplosis trifida* Gagné (Diptera: Cecidomyiidae) for the control of *Melaleuca quinquenervia* (Cav.) S.T. Blake (Myrtales:MyrtacearI in the continental United States. Environmental assessment. United States Department of Agriculture, Animal and Plant Health Inspection Service.

154 Jordan, T. (1997). Host specificity of *Longitarsus quadriguttatus* (Pont., 1765)(Col., Chrysomelidae), an agent for the biological control of hound's tongue (*Cynoglossum officinale* L., Boraginaceae) in North America. *Journal of Applied Entomology*, *121*(1-5), 457-464.

155 Julien, M. H., Kassulke, R. C., & Harley, K. L. S. (1982). *Lixus cribricollis* [Col.: Curculionidae] for biological control of the weeds *Emex spp*. and *Rumex crispus* in Australia. *Entomophaga*, *27*(4), 439-446.

156 Kashefi, J. M., & Sobhian, R. (1998). Notes on the biology of *Larinus minutus* Gyllenhal (Col., Curculionidae), an agent for biological control of diffuse and spotted knapweeds. *Journal of Applied Entomology*, *122*(1-5), 547-549.

157 Kassulke, R. C., Harley, K. L. S., & Maynard, G. V. (1990). Host specificity of *Acanthoscelides quadridentatus* and *A. Puniceus* [Col.: Bruchidae] for biological control of *Mimosa pigra* (with preliminary data on their biology). *Entomophaga*, *35*(1), 85-97.

158 Kay, F., Cuadra, N., Vitorino, M., & Wheeler, G. (2016).Bionomics and host range of *Crasimorpha infuscata* (Lepidoptera: Gelechiidae), a promising biological control agent of *Schinus terebinthifolius* (Anacardiaceae).

159 Khan, A. G., and G. M. Baloch. 1976. *Coleophora klimeschiella* (Lepidoptera: Coleophoridae) - a promising biocontrol agent for Russian thistles, S*asola* spp. In Hawkes, R. B., & Mayfield, A. (1978). *Coleophora klimeschiella*, biological

control agent for Russian thistle: host specificity testing. *Environmental Entomology*, *7(2)*, 257-261.

160 Kingsolver, J.M. (2004). Handbook of the Bruchidae of the United States and Canada (Insecta, Coleoptera) Volume 1. United States Department of Agriculture, Agricultural Research Service. Technical Bulletin. https://www.ars.usda.gov/is/np/Bruchidae/BruchidaeVol1.pdf.

161 Kirkland, R. L., & Goeden, R. D. (1978). Biology of *Microlarinus lareynii* (Col.: Curculionidae) on puncturevine in southern California. *Annals of the Entomological Society of America*, *71*(1), 13-18.

162 Kirkland, R. L., & Goeden, R. D. (1978). Biology of *Microlarinus lypriformis* (Col.: Curculionidae) on puncturevine in southern California. *Annals of the Entomological Society of America*, *71*(1), 65-69.

163 Klein, H. (1999). Biological control of three cactaceous weeds, *Pereskia aculeata* Miller, *Harrisia martinii* (Labouret) Britton and *Cereus jamacaru* De Candolle in South Africa. *African Entomology Memoir*, *1*, 3-14.

164 Klein, O., & Kroschel, J. (2002). Biological control of *Orobanche spp*. with *Phytomyza orobanchia*, a review. *Biocontrol*, *47(3)*, 245-277.

165 Kluge, R. J., & Gordon, A. J. (2004). The fixed plot survey method for determining the host range of the flowerbud-feeding weevil *Dicomada rufa*, a candidate for the biological control of *Hakea sericea* in South Africa. *BioControl*, *49*(3), 341-355.

166 Kluge, R. L. (1983). The hakea fruit weevil, *Erytenna consputa* Pascoe (Coleoptera: Curculionidae), and the biological control of *Hakea sericea* Schrader in South Africa. Dissertation. Rhodes University, South Africa.

167 Kluge, R. L., & Caldwell, P. M. (1993). The biology and host specificity of *Pareuchaetes aurata aurata* (Lepidoptera: Arctiidae), a new association'biological control agent for *Chromolaena odorata* (Compositae). *Bulletin of Entomological Research*, *83*(1), 87-93.

168 Knopf, K. W., & Habeck, D. H. (1976). Life history and biology of *Samea multiplicalis*. *Environmental Entomology*, *5*(3), 539-542.

169 Korneyev, V. A., & White, I. M. (1993). Fruit flies of the genus *Urophora* RD (Diptera: Tephritidae) of East Palaearctic. II. Review of species of the subgenus *Urophora* S. Str.(Communication 1). *Entomological Review*, *72*(5), 35-47.

170 Krauss, N. L. H. (1963). Biological control investigations on Christmas berry (*Schinus terebinthifolius*) and Emex (*Emex spp*.). *Proceedings, Hawaiian Entomological Society*, *18*, 281-284.

171 Krauss, N. L. H. (1964). Some leaf-mining chrysomelids of lantana (Coleoptera). *The Coleopterists' Bulletin*, 92-94.

172 Lang, R. F. (2018). *Terellia virens* (Diptera: Tephritidae). Biological control, A guide to natural Enemies in North America. USDA-APHIS-PPQ, Bozeman Biocontrol facility, Forestry science laboratory, Montana State University, Bozeman, MT 59717- 0278. https://biocontrol.entomology.cornell.edu/weedfeed/Terellia.php.

173 Latto, J., & Briggs, C. J. (1995). Factors affecting distribution of the gall forming midge *Rhopalomyia californica* (Diptera: Cecidomyiidae). *Environmental entomology*, *24*(3), 679-686.

174 Laznik, Ž., & Trdan, S. (2012). Japanese knotweed (*Fallopia japonica* [Houtt.] Ronse Decraene) and its biological control with the psyllid *Aphalara itadori* Shinji. *Acta Agriculturae Slovenica*, *99*(1), 93-98.

175 Le Bourgeois, T., Baret, S., & Desmier de Chenon, R. (2011). Biological control of Rubus alceifolius (Rosaceae) in La Réunion Island (Indian Ocean): from investigations on the plant to the release of the biological control agent Cibdela janthina (Argidae). In Wu, Y., Johnson, T., , Sing, S., Raghu, S., Wheeler, G., Pratt, P., Warner, K., Center, T., Goolsby, J., & Reardon, R. (eds). *Proceedings of the XIII international symposium on biological control of weeds, Waikola, Hawaii*, pp 153.

176 Lewis, P. A., DeLoach, C. J., Knutson, A. E., Tracy, J. L., & Robbins, T. O. (2003). Biology of *Diorhabda elongata* deserticola (Coleoptera: Chrysomelidae), an Asian leaf beetle for biological control of saltcedars (*Tamarix spp*.) in the United States. *Biological control*, *27*(2), 101-116.

177 Littlefield, J. L., Birdsall, J., Helsley, J., & Markin, G. (2000). A petition for the introduction and field release of the Chondrilla root moth, *Bradyrrhoa gilveolella* (Treitschke), for the biological control of rush skeletonweed in North America. United Stattes Department of Agriculrue, Animal and Plant Health Inspection Service, pp *45*.

178 Maddox D. M. (1970) The Bionomics of a stem borer, *Vogtia malloi* (Lepidoptera: Phycitidae) on Alligatorweed in Argentina. *Annals of the Entomological Society of America*, 63, 1267-1273.

179 Maddox, D. M., & Mayfield, A. (1979). Biology and life history of *Amynothrips andersoni*, a thrip for the biological control of alligatorweed. *Annals of the Entomological Society of America*, *72*(1), 136-140.

180 Maddox, D. M., Joley, D. B., & Pitcairn, M. J. (2007). Studies on the biology of the gorse seed weevil, *Exapion ulicis* (Forster 1771), in northern California (Coleoptera: Curculionidae). *The Pan-Pacific Entomologist*, *83*(1), 32-40.

181 Mahna, A. K. (2003). Studies on biology, host Preference and mass multiplication of Mexican Beetle *Zygogramma bicolarata* Pallister. Dissertation, MPUAT, Udaipur.

182 Mann, J. (1969). Cactus-feeding insects and mites. *Smithsonian Institute, Museum of Natural History, Bulletin of the United States National Museum.*

183 Manrique, V. (2007). Temperature-dependent development of the biocontrol agent *Episimus utilis* (Tortricidae), and its potential distribution in Florida.

184 Marohasy, J. (1994). Biology and host specificity of *Weiseana barkeri* (Col.: Chrysomelidae): A biological control agent for *Acacia nilotica* (mimosaceae). *Entomophaga*, *39*(3-4), 335-340.

185 Martelli, G.M., 1933b. Primo contributo alla conoscenza di alcuni parassiti dell'*Orobanche della* Fava (*Orobanche speciosa* D.C.). In Klein, O., & Kroschel, J. (2002). Biological control of *Orobanche spp*. with *Phytomyza orobanchia*, a review. *Biocontrol, 47(3), 245-277.*

186 Martin, C. G., Cuda, J. P., Awadzi, K. D., Medal, J. C., Habeck, D. H., & Pedrosa-Macedo, J. H. (2004). Biology and laboratory rearing of *Episimus utilis* (Lepidoptera: Tortricidae), a candidate for classical biological control of Brazilian peppertree (Anacardiaceae) in Florida. *Environmental entomology*, *33*(5), 1351-1361.

187 Martyn, R. D. (1985). Waterhyacinth decline in Texas caused by *Cercospora piaropi*. *Journal of Aquatic Plant Management*, *23*, 29-32.

188 Masri, R. (1995). Life history studies on *Platypilla isodactyla* a potential biological control agent of ragwort. Dissertation, Honours thesis, La Trobe University, Melbourne.

189 Mazzeo, G., Nucifora, S., Russo, A., & Suma, P. (2019). *Dactylopius opuntiae*, a new prickly pear cactus pest in the Mediterranean: an overview. *Entomologia Experimentalis et Applicata*, *167*(1), 59-72.

190 McAvoy, T. J., & Kok, L. T. (1999). Effects of temperature on eggs, fecundity, and adult longevity of *Hylobius transversovittatus* Goeze (Coleoptera: Curculionidae), a biological control agent of purple loosestrife. *Biological control*, *15*(2), 162-167.

191 McClay, A. S. (1984). Biocontrol agents for *Parthenium hysterophorus* from Mexico. In Delfosse, E. S. (ed). *Proceeding of International Symposium on Biological Control of weed.* Vancouver, Canada.

192 McClay, A. S. (1987). Observations on the biology and host specificity of *Epiblema strenuana* [Lepidoptera, Tortricidae], a potential biocontrol agent for *Parthenium hysterophorus* [Compositae]. *Entomophaga*, *32*(1), 23-34.

193 McClay, A. S. (1996). Biological control in a cold climate: temperature responses and climatic adaptation of weed biocontrol agents. *In* Moran, V. V., & Hoffman, J. H. (eds). *Proceedings of the IX International Symposium on Biological Control of Weeds*, University of Cape Town, South Africa, pp.377-383.

194 McFadyen, P. J. (1987). Host specificity and biology of *Lioplacis elliptica* [Col.: Chrysomelidae] introduced into Australia for the biological control of *Baccharis halimifolia* [Compositae]. *Entomophaga*, *32*(1), 19-21.

195 McFadyen, P. J. (1987). Host-specificity of five *Anacassis* species [Col.: Chrysomelidae] introduced into australia for the biological control of *Baccharis halimifolia* [Compositae]. *Entomophaga*, *32*(4), 377-379.

196 McFadyen, R. E. (1979). *Eriocereophaga humeridens* [Col.: Curculionidae], a potential agent for the biological control of *Eriocereus martinii* [Cactaceae] in Australia. *Entomophaga*, *24*(1), 49-56.

197 McFadyen, R. E. (1985). The biological control programme against *Parthenium hysterophorus* in Queensland. In Delfosse, E. S. (ed). *Proceedings of the VI International Symposium on Biological Control of Weeds,* Vancouver, Canada, pp. 789-796.

198 McFayden, P. J. (1984, August). Introduction of the gall fly *Rhopalomyia californica* from the USA into Australia for the control of the weed *Baccharis halimifolia*. In Delfosse, E. S. (ed). *Proceedings of the VI International Symposium on Biological Control of Weeds*, Vancouver, Canada.

199 McLaren, D. A. (1992). Observations on the life cycle and establishment of *Cochylis atricapitana* (Lep: Cochylidae), a moth used for biological control of *Senecio jacobaea* in Australia. *Entomophaga*, *37*(4), 641-648.

200 Melksham, J. A. (1984). Colonial oviposition and maternal care in two strains of *Leptobyrsa decora* Drake (Hemiptera: Tingidae). *Australian Journal of Entomology*, *23*(3), 205-210.

201 Mo, J., Treviño, M., & Palmer, W. A. (2000). Establishment and distribution of the rubber vine moth, *Euclasta whalleyi* Popescu-Gorj and Constantinescu (Lepidoptera: Pyralidae), following its release in Australia. *Australian Journal of Entomology*, *39*(4), 344-350.

202 Mohammed, H.H., & Abdul-rasoul, M. S. (2013). Biological study of *Hyles euphorbiae* L. (Lepidoptera: Sphingidae) in Kurdistan Region, Iraw. *IOSR journal of Agriculture and Veterinary Science*, *2*(5), 46-49.

203 Mohyuddin, H. I. (1986). Investigations on the natural enemies of *Acacia nilotica* in Pakistan. In Muniappan, R., Reddy, G. V. P., Raman, A. (eds). Biological control of tropical weeds using arthropods. Cambridge University Press, UK.

204 Moran, P. J., & Goolsby, J. A. (2009). Biology of the galling wasp *Tetramesa romana*, a biological control agent of giant reed. *Biological Control*, *49*(2), 169-179.

205 Moran, P. J., & Goolsby, J. A. (2010). Biology of the armored scale *Rhizaspidiotus donacis* (Hemiptera: Diaspididae), a candidate agent for biological control of giant reed. *Annals of the Entomological Society of America*, *103*(2), 252-263.

206 Moran, V. C., & Cabby, B. S. (1979). On the life-history and fecundity of the cochineal insect, *Dactylopius austrinus* De Lotto (Homoptera: Dactylopiidae), a biological control agent for the cactus *Opuntia awantiaca*. *Bulletin of Entomological Research*, *69*(4), 629-636.

207 Morin, L., Hill, R. L., Matayoshi, S., & Whenua, M. (1997). Hawaii's successful biological control strategy for mist flower (*Ageratina riparia*)-can it be transferred to New Zealand?. *Biocontrol News and Information*, *18*, 77N-88N.

208 Morley, T. B. (2004). Host-specificity testing of the boneseed (*Chrysanthemoides monilifera* ssp. *monilifera*) leaf buckle mite (*Aceria neseri*). In Cullen, J. M., Briese, D. T., Kriticos, D. J., Lonsdale, W. M., Morin, L., & Scott, J. K (eds). *XI International Symposium on Biological Control of Weeds,* Canberra, Australia, CSIRO Publishing, pp. 297-300.

209 Moura, L. D. A., & Grazia, J. (2011). Record of *Podisus nigrispinus* (Dallas)(Hemiptera: Pentatomidae) preying on *Metrogaleruca obscura* degeer (Coleoptera: Chrysomelidae). *Neotropical entomology*, *40*(5), 619-621.

210 Moura, M. Z. D., Soares, G. L. G., & Isaias, R. M. D. S. (2009). Ontogenesis of the leaf and leaf galls induced by *Aceria lantanae* Cook (Acarina: Eriophyidae) in *Lantana camara* L. (Verbenaceae). *Brazilian Journal of Botany , 32* (2), 271-282.

211 Mukwevho, L., Olckers, T., & Simelane, D. O. (2017). Establishment, dispersal and impact of the flower-galling mite *Aceria lantanae* (Acari: Trombidiformes: Eriophyidae) on *Lantana camara* (Verbenaceae) in South Africa. *Biological control*, *107*, 33-40.

212 Müller, E., & Nentwig, W. (2011). How to find a needle in a haystack–host plant finding of the weevil *Ceratapion onopordi*. *Entomologia experimentalis et applicata*, *139*(1), 68-74.

213 Müller, H. (1989). Growth pattern of diploid and tetraploid spotted knapweed, *Centaurea maculosa* Lam.(Compositae), and effects of the root-mining moth *Agapeta zoegana* (L.)(Lep.: Cochylidae). *Weed Research, 29*(2), 103-111.

214 Muniappan, R., & Bamba, J. (1999, July). Biological control of Chromolaena odorata: successes and failures. In Spencer, N. R. (ed). *Proceedings of the X international symposium on biological control of weeds,* Montana State University, Bozeman, Montana, USA, pp. 81-85.

215 Mushtaque, M., & Baloch, G. M. (1979). Possibilities of biological control of mistletoes, *Loranthus spp*., using oligophagous insects from Pakistan. *Entomophaga*, *24*(1), 73-81.

216 Nakahara, L. M., Burkhart, R. M., Funasaki, G. Y., Stone, C. P., Tunison, J. T., & Smith, C. W. (1992). Review and status of biological control of *Clidemia* in Hawaii. *Alien plant invasions in native ecosystems of Hawaii: management and research*, 452-465.

217 Nakano, O., Joko, T., & Parra, J. R. P. (1974). Observations on the biology of *Orthezia insignis* Browne, 1887 (Homoptera-Ortheziidae). *Anais de Sociedade Entomologica do Brasil*, *3*(1), 44-48.

218 Nelson, HS (1962). Studies on the biological control of *Hypericum perforatum* L. with the help of insects (*Chrysomela varians* Schall., Coleoptera, and *Semasia hypericana* Hb., Lepidoptera 1). *Journal of Applied Entomology*, *50* (1-4), 290-327.

219 Neser, S. (1968). Studies on insect ene mies of needle-bushes. Dissertation, Australian National University, Can berra.

220 Neser, S., & Kluge, R. L. (1984). A Seed-feeding insect showing promise in the control of a woody, invasive plant: the Weevil *Erytenna consputa*. Delfosse, E. S (ed). *Proceeding of the VI International Symposium on Biological Control of Weeds,* Vancouver, Canada, pp. 805-809.

221 Nieman, E. (1983). An evaluation of *Mimorista pulchellalis* (Dyar)[Lepidoptera: Pyraustidae] as a biocontrol agent against jointed cactus in South Africa. M. Sc. thesis., Rhodes University, Grahamstown.

222 Nuzzaci, G., Mimmocchi, T., & Clement, S. L. (2016). A new species of *Aceria* (Acari: Eriophyidae) from *Convolvulus arvensis* L.(Convolvulaceae) with notes on other eriophyid associates of convolvulaceous plants. *Entomologica, 20*, 81-89.

223 Oberholzer, I. G., & Hill, M. P. (2001). How safe is the grasshopper *Cornops aquaticum* for release on water hyacinth in South Africa. In Julien, M. H., Hill, M. P., Center, T. D., & Jianqing, D. (eds). *Proceedings of the Second Meeting of the Global Working Group for the Biological and Integrated Control of Water Hyacinth*, pp.82-88.

224 O'Brien, C. W. (1976). *Eriocereophaga humeridens*, a new genus and species and potential biological control agent from Brazil (Cryptorhynchinae, Curculionidae, Coleoptera). *The Coleopterists' Bulletin*, 303-307.

225 Olckers, T. (2000). Biology, host specificity and risk assessment of *Gargaphia decoris*, the first agent to be released in South Africa for the biological control of the invasive tree *Solanum mauritianum*. *BioControl*, *45*(3), 373-388.

226 Olckers, T., Zimmermann, H. G., & Hoffmann, J. H. (1995). Interpreting ambiguous results of host-specificity tests in biological control of weeds: assessment of two *Leptinotarsa* species (Chrysomelidae) for the control of *Solanum elaeagnifolium* (Solanaceae) in South Africa. *Biological Control*, *5*(3), 336-344.

227 Oosthuizen, M. J. (1964). The biological control of Lantana camara L. in Natal. *Journal of the Entomological Society of Southern Africa*, *27*(1), 03-16.

228 Ozman, S. K., & Goolsby, J. A. (2005). Biology and phenology of the eriophyid mite, *Floracarus perrepae*, on its native host in Australia, Old World climbing fern, *Lygodium microphyllum*. *Experimental & applied acarology*, *35*(3), 197.

229 Palmer, W. A., & Senaratne, K. A. D. W. (2007). The host range and biology of *Cometaster pyrula*; a biocontrol agent for *Acacia nilotica* subsp. *indica* in Australia. *BioControl*, *52*(1), 129-143.

230 Palmer, W. A., Willson, B. W., & Pullen, K. R. (2000). Introduction, rearing, and host range of *Aerenicopsis championi* Bates (Coleoptera: Cerambycidae) for the Biological Control of *Lantana camara* L. in Australia. *Biological Control*, *17*(3), 227-233.

231 Peschken, D. P., & Beecher, R. W. (1973). *Ceutorhynchus litura* (Coleoptera: Curculionidae): biology and first releases for biological control of the weed Canada thistle (*Cirsium arvense*) in Ontario, Canada. *The Canadian Entomologist*, *105*(12), 1489-1494.

232 Peschken, D. P., & Johnson, G. R. (1979). Host specificity and suitability of *Lema cyanella* (Coleoptera: Chrysomelidae), a candidate for the biological control of Canada thistle (*Cirsium arvense*). *The Canadian Entomologist*, *111*(9), 1059-1068.

233 Piper, G. L. (1975). The biology and immature stages of *Zygogramma Suturalis* (Fabricius)(Coleoptera: Chrysomelidae). *The Ohio Journal of Science*, *75*, 19-24.

234 Piper, G. L. (1978). Life history of *Zygogramma disrupta* in southeast Texas (Coleoptera: Chrysomelidae). *Pan-Pacific Entomologist*, *54*(3), 226-230.

235 Piwowarczyk, R., Mielczarek, Ł., Panek-Wójcicka, M., & Ruraż, K. (2020). First report of *Melanagromyza cuscutae* (Diptera: Agromyzidae) from Poland. *Florida Entomologist*, *103*(1), 124-126.

236 Plant Parasite of Europe. (2019). *Apiion frumentatrium*. https://bladmineerders.nl/parasites/animalia/arthropoda/insecta/coleoptera/polyphaga/cucujiformia/curculionoidea/apionidae/apioninae/apionini/apionina/apion/apion-frumentarium/.

237 Plant Parasite of Europe. (2019). Urophora terebrans. https://bladmineerders.nl/parasites/animalia/arthropoda/insecta/diptera/brachycera/tephritidae/urophora/urophora-terebrans/.

238 Purcell, M. F., & Balciunas, J. K. (1994). Life history and distribution of the Australian weevil *Oxyops vitiosa* (Coleoptera: Curculionidae), a potential

biological control agent for *Melaleuca quinquenervia* (Myrtaceae). *Annals of the Entomological Society of America*, *87*(6), 867-873.

239 Purcell, M. F., Balciunas, J. K., & Jones, P. (1997). Biology and host-range of *Boreioglycaspis melaleucae* (Hemiptera: Psyllidae), potential biological control agent for *Melaleuca quinquenervia* (Myrtaceae). *Environmental Entomology*, *26*(2), 366-372.

240 Ramadan, M. M. (2014). Blackberry skeletonizer moth, *Schreckensteinia festaliella*: natural distribution and egg parasitism on six Rubus species in tropical Hawaiian rainforest (Poster). In *XIV International Symposium on Biological Control of Weeds*, Kruger National Park, South Africa. https://www.researchgate.net/profile/Mohsen-Ramadan-2/publication/268334739_Blackberry_skeletonizer_moth_Schreckensteinia_festaliella_natural_distribution_and_egg_parasitism_on_six_Rubus_species_in_tropical_Hawaiian_rainforest/links/546973870cf2f5eb1804edfd/Blackberry-skeletonizer-moth-Schreckensteinia-festaliella-natural-distribution-and-egg-parasitism-on-six-Rubus-species-in-tropical-Hawaiian-rainforest.pdf.

241 Raman, A., Cruz, Z. T., Muniappan, R., & Reddy, G. V. (2007). Biology and host specificity of gall-inducing *Acythopeus burkhartorum* (Coleoptera: Curculionidae), a biological-control agent for the invasive weed *Coccinia grandis* (Cucurbitaceae) in Guam and Saipan. *Tijdschrift voor Entomologie*, *150*(1), 181-191.

242 Ramesha, B. (2015). Notes on the baridine weevil genus *Acythopeus* (Coleoptera: Curculionidae) from India. *Indian Journal of Entomology*, *77*(4), 363-382.

243 Reimer, N. J., & Beardsley Jr, J. W. (1989). Effectiveness of *Liothrips urichi* (Thysanoptera: Phlaeothripidae) introduced for biological control of *Clidemia hirta* in Hawaii. *Environmental entomology*, *18*(6), 1141-1146.

244 Ribeiro, S. D. C. (2014). *Acacia longifolia* and gall networks in Portugal: Understanding the impacts and the implications for biocontrol. M. S. thesis, Universidade De Coimbra.

245 Richerson, P. J., & Grigarick, A. A. (1967). The life history of *Stenopelmus rufinasus* (Coleoptera: Curculionidae). *Annals of the Entomological Society of America*, *60*(2), 351-354.

246 Rizza, A. (1977). *Phrydiuchus spilmani* and *P. tau*: Cross-mating, egg production, and larval head capsule size. *Annals of the Entomological Society of America*, *70*(1), 7-10.

247 Rizza, A., Campobasso, G., Dunn, P. H., & Stazi, M. (1988). *Cheilosia corydon* (Diptera: Syrphidae), a candidate for the biological control of musk thistle in North America. *Annals of the Entomological Society of America*, *81*(2), 225-232.

248 Robbins, W. H. G., Lovero, C. D. A., Mayer, M., & Beetle, J. (2014). *Rhinoncomimus latipes* (Coleoptera: Curculionindae) As a biological control agent for mile-a-minute, *Persicaria perfoliata* in New Jersey. *Annual Report*. Phillip Alampi Beneficial Insect Laboratory, Division of Plant Industry.

249 Rosenthal, S. S., Clement, S. L., Hostettler, N., & Mimmocchi, T. (1988). Biology of *Tyta luctuosa* [Lep.: Noctuidae] and its potential value as a biological control agent for the weed *Convolvulus arvensis*. *Entomophaga*, *33*(2), 185-192.

250 Sagliocco, J. L., & Coupland, J. B. (1995). Biology and host specificity of *Chamaesphecia mysiniformis* (Lepidoptera: Sesiidae), a potential biological control agent of *Marrubium vulgare* (Lamiaceae) in Australia. *Biocontrol science and technology*, *5*(4), 509-516.

251 Sands, D. P. A., Schotz, E. M., & Bourne, F. A. S. (1986). A comparative study on the intrinsic rates of increase of *Cyrtobagous singularis* and *C. salviniae* on the water weed *Salvinia molesta*. *Entomologia experimentalis et applicata*, *42*(3), 231-237.

252 Sands, D.P.A., Kassulke, R.C., 1983. *Acigona infusella* (Walker) (Lepidoptera: Pyralidae), an agent for biological control of waterhyacinth (*Eichhornia crassipes*) in Australia. In Stanley, J. N., Julien, M. H., & Center, T. D. (2007). Performance and impact of the biological control agent *Xubida infusella* (Lepidoptera; Pyralidae) on the target weed *Eichhornia crassipes* (waterhyacinth) and on a non-target plant, *Pontederia cordata* (pickerelweed) in two nutrient regimes. *Biological Control, 40(3)*, 298-305.

253 Sankaran, T., Rajendran, M. K., & Bhat, Y. R. (1969). Biology of *Eulocastra argentisparsa* Hampson (Lep.: Noctuidae) with special reference to the occurrence of dimorphism.

254 Schaber, B. D., Balsbaugh, E. U., & Kantack, B. H. (1975). Biology of the flea beetle, *Altica carduorum* [Col.: Chrysomelidae] on Canada thistle (*Cirsium arvense*) in South Dakota. *Entomophaga*, *20*(4), 325-335.

255 Schmidl, L. (1972). Studies on the control of ragwort, *Senecio jacobaea* L., with the cinnabar moth, *Callimorpha jacobaeae* (L.)(Arctiidae: Lepidoptera), in Victoria. *Weed research*, *12*(1), 46-57.

256 Schmidt, F., Hoffmann, J. H., & Donnelly, D. (1999). Levels of damage caused by *Melanterius servulus* Pascoe (Coleoptera: Curculionidae), a seed-feeding weevil introduced into South Africa for biological control of *Paraserianates lophantha* (Fabaceae). *African entomology*, *7*(1), 107-112.

257 Schutte, B. J., Beck, L. L., Sutherland, C., Jimenez, D., & Hamilton, W. V. Managing *Aceria malherbae* gall mites for control of field bindweed. Collage of Agriculture, Consumer and Environmental Sciences, cooperative extension service, Circular 600, New Mexico State University. https://aces.nmsu.edu/pubs/_circulars/CR600.pdf.

258 Schwarzlaender, M. (1997). Bionomics of *Mogulones cruciger* (Coleoptera: Curculionidae), a below-ground herbivore for the biological control of hound's-tongue. *Environmental Entomology*, *26*(2), 357-365.

259 Scott, J. K., & Yeoh, P. B. (2005). Biology and host specificity of *Apion miniatum* (Coleoptera: Apionidae) from Israel, a potential biological control agent for *Emex australis* and *Emex spinosa* (Polygonaceae) in Australia. *Biological Control*, *33*(1), 20-31.

260 Sforza, R., & Jones, W. A. (2007). Potential for classical biocontrol of silverleaf nightshade in the Mediterranean Basin. *EPPO bulletin*, *37*(1), 156-162.

261 Shaw, R. H., Bryner, S., & Tanner, R. (2009). The life history and host range of the Japanese knotweed psyllid, *Aphalara itadori* Shinji: potentially the first classical biological weed control agent for the European Union. *Biological Control*, *49*(2), 105-113.

262 Shoba, Z., & Olckers, T. (2010). Reassessment of the biology and host range of *Acanthoscelides macrophthalmus* (Chrysomelidae: Bruchinae), a seed-feeding beetle released for the biological control of *Leucaena leucocephala* in South Africa. *African Entomology*, *18*(2), 1-10.

263 Shorthouse, J. D., & Gassmann, A. (1994). Gall induction by *Pegomya curticornis* (Stein)(Diptera: Anthomyiidae) within the roots of spurges *Euphorbia virgata* Waldst. and Kit. and *E. esula* L.(Euphorbiaceae). *The Canadian Entomologist*, *126*(2), 193-197.

264 Simelane, D. O. (2010). Potential impact of an introduced root-feeding flea beetle, *Longitarsus bethae*, on the growth and reproduction of an invasive weed, *Lantana camara*. *Biological Control*, *54*(2), 114-118.

265 Smith, D. R. (2003). A synopsis of the sawflies (Hymenoptera: Symphyta) of America south of the United States: Tenthredinidae (Allantinae). *Journal of Hymenoptera Research*, *12*(1), 148-192.

266 Smith, G. R., & Cole, A. L. J. (1991). *Phoma clematidina*, causal agent of leafspot and wilt of Clematis in New Zealand. *Australasian Plant Pathology*, *20*(2), 67-72.

267 Snow, E. L., Palmer, W. A., & Senaratne, K. W. (2012). The release of *Plectonycha correntina*, a leaf feeding beetle for the biological control of Madeira vine. In Eldershaw, V. (ed.). *Conference proceedings from the Eighteenth Australasian Weeds Conference*, Melbourne, Australia, pp. 339-342.

268 Sobhian R., Campobasso G., & Dunn P.H. (1992). A contribution to the biology of *Bangasternus fausti* [Col.: Curculionidae], a potential biological control agent of diffuse knapweed, *Centaurea diffusa*, and its effect on the host plant. *Entomophaga*, 37, 171-179.

269 Sobhian, R. (1993). Life history and host specificity of *Urophora sirunaseva* (Hering)(Dipt., Tephritidae), a candidate for biological control of yellow starthistle, with remarks on the host plant. *Journal of Applied Entomology*, *116*(1-5), 381-390.

270 Sobhian, R., & Andres, L. A. (1978). The response of the skeletonweed gall midge, *Cystiphora schmidti* (Diptera: Cecidomyiidae), and gall mite, *Aceria chondrillae* (Eriophyidae) to North American strains of rush skeletonweed (*Chondrilla juncea*). *Environmental Entomology*, *7*(4), 506-508.

271 Solis, M. A., Metz, M. A., & Zachariades, C. (2008). Identity and generic placement of *Phestinia costella* Hampson (Lepidoptera: Pyralidae: Phycitinae) reared on the invasive plant *Chromolaena odorata* (L.) RM King & H. Rob.(Asteraceae). *Proceedings of the Entomological Society of Washington*, *110*(3), 679-692.

272 Sommer, G. and E. Maw. 1982. *Aphthona cyparissiae* (Koch) and *A. flava* Guill. (Coleoptera: Chrysomelidae): Two candidates for the biological control of cypress and leafy spurge in North America. Intl. Inst. of Biol. Contr., Delémont,

Switzerland. Final report: 42.
https://www.team.ars.usda.gov/cdgallery/doc/acyparissiae.pdf

273 Sosa, A. J., Lenicov, A. M. D. R., Mariani, R., & Cordo, H. A. (2004). Redescription of *Megamelus scutellaris* Berg (Hemiptera: Delphacidae), a candidate for biological control of water hyacinth. *Annals of the Entomological Society of America*, *97*(2), 271-275.

274 Sosa, A. J., Lenicov, A. M. M. D. R., Mariani, R., & Cordo, H. A. (2005). Life history of *Megamelus scutellaris* with description of immature stages (Hemiptera: Delphacidae). *Annals of the Entomological Society of America*, *98*(1), 66-72.

275 Spafford, H., Hawley, J., & Strickland, G. (2008). Survival of dock moth larvae, *Pyropteron doryliformis* (Lepidoptera: Sesiidae), in tubers of fiddle dock (Rumex pulcher). In *Proceedings of the 16th Australian Weeds Conference, Cairns Convention Centre, North Queensland, Australia*, pp. 272-274).

276 Stark, J. D., & Goyer, R. A. (1983). Life cycle and behavior of *Neochetina eichhorniae* Warner (Coleoptera: Curculionidae) in Louisiana: a biological control agent of waterhyacinth. *Environmental Entomology*, *12*(1), 147-150.

277 Stegmaier, C. E. (1967). *Pluchea Odorata*, a New Host Record for *Acinia picturata* (Diptera, Tephritidae). *The Florida Entomologist*, *50*(1), 53-55.

278 Steinbauer, M. J., Edwards, P. B., Hoskins, M., Schatz, T., & Forno, I. W. (2000). Seasonal abundance of insect biocontrol agents of *Mimosa pigra* in the Northern Territory. *Australian Journal of Entomology*, *39*(4), 328-335.

279 Stoltzfus, W. B. (1974). The biology and taxonomy of *Eutreta* (Diptera: Tephritidae). Dissertations, Iowa State University.

280 Stride, G. O., & Straatman, R. (1963). On the biology of *Mews saturnina* and *Nupserha antennata*, cerambycid beetles associated with *Xantlzium* species. In Wapshere, A. J. (1974). An ecological study of an attempt at biological control of *Noogoora burr* (*Xanthium strumarium*). *Australian Journal of Agricultural Research*, 25(2), 275-292.

281 Sullivan, P. R. (1990). Population growth potential of *Dactylopius ceylonicus* Green (Hemiptera: Dactylopiidae) on *Opuntia vulgaris* Miller. *Australian Journal of Entomology*, *29*(2), 123-129.

282 Sullivan, P., & Postle, L (2012). Salvina biological control field guide. https://www.dpi.nsw.gov.au/__data/assets/pdf_file/0008/425807/Salvinia-biological-control-field-guide.pdf

283 Swirepik, A., Aveyard, R., Holtkamp, R., & Stephenson, P. (2004). The release and establishment of the bitou bush agent *Tortrix sp*. in New South Wales from 2001-2004. In Sindle, B. M., & Johnson, S. B. (eds). *Weed management: balancing people, planet, profit. 14th Australian Weeds Conference*, Wagga Wagga, New South Wales, Australia pp. 353-356.

284 Syrett, P., Fowler, S. V., Coombs, E. M., Hosking, J. R., Markin, G. P., Paynter, Q. E., & Sheppard, A. W. (1999). The potential for biological control of Scotch broom (*Cytisus scoparius*)(Fabaceae) and related weedy species. *Biocontrol News and Information*, *20*, 17N-34N.

285 Syrett, P., Harman, H. M., Grosskopf, G., & Smith, L. A. (1996). Insects for biological control of H*ieracium* in New Zealand: a progress report. In Moran, V. C., & Hoffman, J. H. (eds). *Proceedings of the IX International Symposium on Biological Control of Weeds,* Stellenbosch, South Africa, University of Cape Town, pp. 213-218.

286 Tafoya, F., Lopez-Collado, J., Stanley, D., Rojas, J. C., & Cibrian-Tovar, J. (2003). Evidence of an aggregation pheromone in males of *Metamasius spinolae* (Coleoptera: Curculionidae). *Environmental entomology*, *32*(3), 484-487.

287 Tawfik, M.F.S., K.T. Awadallah and F.F. Shalaby, 1976. Biology of *Phytomyza orobanchia* Kalt. (Diptera; Agromyzidae). *In* Klein, O., & Kroschel, J. (2002). Biological control of *Orobanche spp*. with *Phytomyza orobanchia*, a review. *Biocontrol*, *47(3)*, 245-277.

288 Thomas, P. A. (1980). Life-cycle studies on *Paulinia acuminata* (DeGeer)(Orthoptera: Pauliniidae) with particular reference to the effects of constant temperature. *Bulletin of Entomological Research*, *70*(3), 381-389.

289 Trujillo, E. E., Latterell, F. M., & Rossi, A. (1986). *Colletotrichum gloeosporioides*, a possible biological control agent for *Clidemia hirta* in Hawaiian forests. *Plant Disease*, *70*(10), 974-976.

290 Turner, C. E., Piper, G. L., & Coombs, E. M. (1996). *Chaetorellia australis* (Diptera: Tephritidae) for biological control of yellow starthistle, *Centaurea solstitialis* (Compositae), in the western USA: establishment and seed destruction. *Bulletin of entomological research*, *86*(2), 177-182.

291 Uyi, O. O., Zachariades, C., & Hill, M. P. (2014). The life history traits of the arctiine moth *Pareuchaetes insulata*, a biological control agent of *Chromolaena odorata* in South Africa. *African Entomology*, *22*(3), 611-624.

292 Uyi, O. O., Zachariades, C., Marais, E., & Hill, M. P. (2017). Reduced mobility but high survival: thermal tolerance and locomotor response of the specialist herbivore, *Pareuchaetes insulata* (Walker)(Lepidoptera: Erebidae), to low temperatures. *Bulletin of entomological research*, *107*(4), 448-457.

293 van Klinken, R. D., & Heard, T. A. (2000). Estimating fundamental host range: a host-specificity study of a biocontrol agent for *Prosopis* species (Leguminosae). In van Klinken, R. D., Hoffmann, J. H., Zimmermann, H. G., & Roberts, A. P. (2009). *Prosopis* species (Leguminosae). *Biological control of tropical weeds using arthropods*, 353-377.

294 van Klinken, R.D. (2000). Host-specificity constrains evolutionary host change in the psyllid *Prosopidopsylla flava*. In van Klinken, R. D., Fichera, G., & Cordo, H. (2003). Targeting biological control across diverse landscapes: the release, establishment, and early success of two insects on mesquite (*Prosopis spp*.) insects in Australian rangelands. *Biological Control*, *26*(1), 8-20.

295 varians Schaller, C. (1990). Observations on the reproduction and development of the viviparous leaf beetle *Chrysomela varians* Schaller (Coleoptera, Chrysome-lidae). *Acta Biol. Benrodis*, 2, 71.78.

296 Vayssieres, J. F., & Wapshere, A. J. (1983). Life–histories and host specificities of *Ceutorhynchus geographicus* (Goeze) and *C. larvatus* Schultze (Coleoptera: Curculionidae), potential biological control agents for *Echium*. *Bulletin of Entomological Research*, *73*(3), 431-440.

297 Visalakshy, P. G., & Jayanth, K. P. (1990). Studies on the biology and seasonal abundance of *Hypena laceratalis* Walker (Lepidoptera: Noctuidae) on *Lantana camara* L. in India. *Entomon*, *15*(3-4), 231-234.

298 Vitou, J., Briese, D. T., Sheppard, A. W., & Thomann, T. (2001). Comparative biology of two rosette crown-feeding flies of the genus *Botanophila* (Dipt., Anthomyiidae) with potential for biological control of their thistle hosts. *Journal of applied Entomology*, *125*(1-2), 89-95.

299 Wadswokth, J. (1914). Some observation on the lifehistory and bionomics of the knapweed gall fly, *Urophora solstitialis* Linn. *Annals of Applied Biology*, *1*(2), 142-169.

300 Wager-Page, S. (2009). Field Release of *Jaapiella ivannikovi* (Diptera: Cecidomyiidae), an insect for biological control of russian knapweed (*Acroptilon repens*), in the Continental United States. Environmental assessment. United States Department of Agriculture, Animal and Plant Health Inspection Service.

301 Walton, A. J., & Conlong, D. E. (2003). Laboratory rearing of *Pareuchaetes insulata* (Lepidoptera: Arctiidae), a biological control agent of *Chromolaena odorata* (Asteraceae). In *Proc S Afr Sug Technol Ass*, pp. 200-204.

302 Wapshere, A. J. (1974). An ecological study of an attempt at biological control of Noogoora burr (*Xanthium strumarium*). Australian Journal of Agricultural Research, 25(2), 275-292.

303 Wapshere, A. J. (1982). Life histories and host specificities of the Echium flea beetles *Longitarsus echii* and L. *Aeneus* [Col. Chrysomelidae]. *Entomophaga*, *27*(2), 173-181.

304 Wapshere, A. J., & Kirk, A. A. (1977). The biology and host specificity of the Echium leaf miner *Dialectica scalariella* (Zeller)(Lepidoptera: Gracillariidae). *Bulletin of Entomological Research*, *67*(4), 627-633.

305 Ward, R. H., & Pienkowski, R. L. (1978). Biology of *Cassida rubiginosa* a Thistle-Feeding Shield Beetle. *Annals of the Entomological Society of America*, *71*(4), 585-591.

306 Waterhouse, D. F. (1993). Biological control pacific prospects-supplement 2 (No. 435-2016-33743). *Australian Center for International Agriculture Research*, Canberra.

307 Watson, A. K. (1986). Biology of *Subanguina picridis*, a potential biological control agent of Russian knapweed. *Journal of nematology*, 18(2), 149.

308 Wheeler, G. S., Van, T. K., & Center, T. D. (1998). Fecundity and egg distribution of the herbivore *Spodoptera pectinicornis* as influenced by quality of the floating aquatic plant *Pistia stratiotes*. *Entomologia experimentalis et applicata*, *86*(3), 295-304.

309 Williams, H. E. (2002). Life history and laboratory host range of *Charidotis auroguttata* (Boheman)(Coleoptera: Chrysomelidae), the first natural enemy released against *Macfadyena unguis-cati* (L.) Gentry (Bignoniaceae) in South Africa. *The Coleopterists' Bulletin*, 299-307.

310 Williams, H. E. (2003). Host Specificity Report to the National Department of Agriculture: Directorate of Plant Health and Quality in relation to an application for permission to undertake the release of *Hylaeogena* (*Hedwigiella*) *jureceki* Obenberger, a biological control agent for *Macfadyena unguis-cati* L. Gentry (Bignoniaceae) in South Africa. In Dhileepan, K., Taylor, D. B. J., Lockett, C., & Trevino, M. (2011). Application to release *Hylaeogena jureceki* Obenberger (Coleoptera: Buprestidae), a potential biological control agent for cat's claw creeper *Macfadyena unguis-cati* L. Gentry (Bignoniaceae). *Queensland Department of Employment, Economic Development & Innovation*.

311 Williams, J. R. (1960). The control of black sage (*Cordia macrostachya*) in Mauritius: the introduction, biology and bionomics of a species of *Eurytoma* (Hymenoptera, Chalcidoidea). *Bulletin of Entomological Research*, *51*(1), 123-133.

312 Willis, A. J. (1994). The ecology of *Hypericum gramineum* with reference to biological control of *H*. *perforatum* by the mite, *Aculus hyperici*. Dissertation, Australian National University.

313 Willson, B. W., & Garcia, C. A. (1992). Host specificity and biology of *Heteropsylla spinulosa* [Hom.: Psyllidae] introduced into Australia and Western Samoa for the biological control of *Mimosa invisa*. *Entomophaga*, *37*(2), 293-299.

314 Wilson, L. M., & Mccaffrey, J. P. (1993). Bionomics of *Phrydiuchus tau* (Coleoptera: Curculionidae) associated with Mediterranean sage in Idaho. *Environmental entomology*, *22*(3), 704-708.

315 Wilson, L. M., Jette, C., Connett, J., & McAffrey, J. (2003). Biology and biological control of yellow starthistle. USDA Forest Service, Forest Health Technology Entreprise Team.

316 Wilson, L. M., Schwarzlaender, M., Blossey, B., & Randall, C. B. (2004). Biology and biological control of purple loosestrife. USDA Forest Service, Forst Health Technology Enterprise Team.

317 Winder, J. A., Sands, D. P. A., & Kassulke, R. C. (1988). The life history, host specificity and potential of *Alagoasa parana* Samuelson (Coleoptera: Chrysomelidae) for biological control of *Lantana camara* in Australia. *Bulletin of entomological research*, *78*(3), 511-518.

318 Wineriter, S. A., Halbert, S. E., & Cuda, J. P. (2003). *A Psyllid, Boreioglycaspis melaleucae Moore (Insecta: Hemiptera: Psyllidae)*. University of Florida Cooperative Extension Service, Institute of Food and Agricultural Sciences.

319 Winston, R., Randall, C. B., De Clercj-Floate, R., McClay, A., Andreas, J., & Schwarzländer, M. (2017). *Field guide for the biological control of weeds in the Northwest*. Forest Health Technology Entreprise Team, FHTET-2014-08.

320 Winston, R., Schwarzlander, M., Randall, C. B., & Reardon, R. (2010). Biology and biological control of common St. Johnsworts. Forest Health Technology Enterprise Team.

321 Winston, R., Schwarzlander, M., Randall, C. B., & Reardon, R. (2012). Biology and biological control of knapweeds. Forest Health Technology Enterprise Team.

322 Witt, A. B. R., & Edwards, P. B. (2000). Biology, distribution, and host range of *Zygina* sp.(Hemiptera: Cicadellidae), a potential biological control agent for *Asparagus asparagoides*. *Biological Control*, *18*(2), 101-109.

323 Witt, A. B. R., & Edwards, P. B. (2002). Aspects of the biology, distribution, and host range of *Crioceris sp*.(Col.: Chrysomelidae: Criocerinae), a potential biological control agent for *Asparagus asparagoides* in Australia. *Biological Control*, *23*(1), 56-63.

324 Wittenberg, R. (1994). Investigations on potential bio-control agents of old man's beard, *Clematis vitalba*. *Annual repor*t, International Institute of Biological Control. Delémont, Switzerland.

325 Woods, W. (1984). Bruchid Seed Beetles for Control of *Parkinsonia aculeata* in Australia. In Delfossee, E. S. (ed). *Proceeding of the VI International Symposium on Biological Control of Weeds*, Vancouver, Canada, pp. 854-862.

326 Yen, S. H., Solis, M. A., & Goolsby, J. A. (2004). *Austromusotima*, a new Musotimine genus (Lepidoptera: Crambidae) feeding on Old World climbing fern, *Lygodium microphyllum* (Schizaeaceae). *Annals of the Entomological Society of America*, *97*(3), 397-410.

327 Zachariades, C., Strathie, L. W., & Kluge, R. L. (2002). Biology, host specificity and effectiveness of insects for the biocontrol of Chromolaena odorata in South Africa. In Zachariades, C., Muniappan, R., & Strathie, L. W. (eds). *Proceedings of the Fifth International Workshop on Biological Control and Management of Chromolaena odorata*, Durban, South Africa, pp. 160-166.

328 Zhang, X., Xi, Y., Zhou, W., & Kay, M. (1993). *Cleopus japonicus*, a potential biocontrol agent for *Buddleja davidii* in New Zealand. *New Zealand Journal of Forestry Science*, *23*(1), 78-83.

329 Zhigang, L., Shichou, H., Mingfang, G., Lifeng, L., Liying, L., & de Chenon, R. D. (2004). Rearing *Actinote thalia pyrrha* (Fabricius) and *Actinote anteas* (Doubleday and Hewitson) with cutting and potted *Mikania micrantha* Kunth. In Day, M. D., & McFadyen, R. E. (eds). *Chromolaena in the Asia-Pacific region, Proceedings of the 6th International Workshop on biological control andmanagement of chromolaena*, Australia.

330 Zwölfer, H., & Harris, P. (1966). *Ceutorhynchus litura* (F.)(Col. Curculionidae), a potential insect for the biological control of thistle, *Cirsium arvense* (L.) Scop., in Canada. *Canadian Journal of Zoology*, *44*(1), 23-38.

331 Zwölfer, H., & Harris, P. (1984). Biology and host specificity of *Rhinocyllus conicus* (Froel.)(Col., Curculionidae), a successful agent for biocontrol of the thistle, *Carduus nutans* L. 1. *Zeitschrift für angewandte Entomologie*, *97*(1-5), 36-62.

332 Zwölfer, H., & Pattullo, W. (1969). Zur Lebensweise und Wirtsbindung des Distel-BlattkäfersLema cyanella L.(puncticollis Curt.)(Col. Chrysomelidae). *Anzeiger für Schädlingskunde*, *42*(4), 53-59.

Appendix D Reference lists used to collect information on life history traits of target weeds

1 Abud, H. F., Pereira, M. D. S., Gonçalves, N. R., Pereira, D. D. S., & Bezerra, A. M. E. (2013). Germination and morphology of fruits, seeds and plants of *Cereus jamacaru* DC. *Journal of Seed Science*, *35*(3), 310-315.

2 Adkins, S., & Shabbir, A. (2014). Biology, ecology and management of the invasive parthenium weed (*Parthenium hysterophorus* L.). *Pest Management Science*, *70*(7), 1023-1029.

3 Aigbokhan, E. I., Berner, D. K., & Musselman, L. J. (1998). Reproductive ability of hybrids of *Striga aspera* and *Striga hermonthica*. *Phytopathology*, *88*(6), 563-567.

4 Albrecht, M., Duelli, P., Obrist, M. K., Kleijn, D., & Schmid, B. (2009). Effective long-distance pollen dispersal in *Centaurea jacea*. *PLOS One*, *4*(8), e6751.

5 Alex, J. F. (1962). The taxonomy, history, and distribution of *Linaria dalmatica*. *Canadian Journal of Botany*, *40*(2), 295-307.

6 Allen, L. J. S., Allen, E. J., Kunst, C. R. G., & Sosebee, R. E. (1991). A diffusion model for dispersal of *Opuntia imbricata* (cholla) on rangeland. *The Journal of Ecology*, 1123-1135.

7 Amor, R. L. (1974). Ecology and control of blackberry (*Rubus fruticosus* L. agg.) II. Reproduction. *Weed Research*, *14*(4), 231-238.

8 Anderson, E.F., Barthlott, W., and Brown, R. (2001). The Cactus Family. In Balandrán-Quintana, R. R., González-León, A., Islas-Rubio, A. R., Madera-Santana, T. J., Soto-Valdez, H., Mercado-Ruiz, J. N., ... & Granados-Nevarez, M. C. An overview of Cholla (*Cylindropuntia* spp.) from Sonora, Mexico.

9 Andersson, S. (2001). The genetic basis of floral variation in *Senecio jacobaea* (Asteraceae). *Journal of Heredity*, *92*(5), 409-414.

10 Andrews, F. W. (1946). A Study of nut grass (*Cyperus rotundus* L.) in the cotton soil of the Gezira: II. The perpetuation of the plant by means of seed. *Annals of Botany*, *10*(37), 15-30.

11 Arnold, R. M. (1982). Pollination, predation and seed set in *Linaria vulgaris* (Scrophulariaceae). *American Midland Naturalist*, *107(2)*, 360-369.

12 Atlan, A., Schermann-Legionnet, A., Udo, N., & Tarayre, M. (2015). Self-incompatibility in *Ulex europaeus*: variations in native and invaded regions. *International Journal of Plant Sciences*, *176*(6), 515-524.

13 Auld, B. A. (1988). Dynamics of pasture invasion by three weeds, *Avena fatua* L., *Carduus tenuiflorus* Curt. and *Onopordum acanthium* L. *Australian Journal of Agricultural Research*, *39*(4), 589-596.

14 Auld, B. A., & Martin, P. M. (1975). The autecology of *Eupatorium adenophorum* Spreng. in Australia. *Weed Research*, *15*(1), 27-31.

15 Austin, D. F. (1980). Studies of the Florida Convolvulaceae—III. Cuscuta. *Florida Scientist*, 294-302.

16 Australian Native Plants Society (n.d). *Leptospermum laevigatum*. http://anpsa.org.au/l-lae.html.

17 Bailey, L. H. (1949). Manual of cultivated plants most commonly grown in the continental United States and Canada. In Peterson, D. J., & Prasad, R. (1998). The biology of Canadian weeds. 109. *Cytisus scoparius* (L.) Link. *Canadian journal of plant science*, 78(3), 497-504.

18 Bailey, M. F., & McCauley, D. E. (2006). The effects of inbreeding, outbreeding and long-distance gene flow on survivorship in North American populations of *Silene vulgaris*. *Journal of Ecology*, 98-109.

19 Bain, J. F. (1991). The biology of Canadian weeds.: 96. *Senecio jacobaea* L. *Canadian Journal of Plant Science*, *71*(1), 127-140.

20 Bajwa, A. A., Chauhan, B. S., Farooq, M., Shabbir, A., & Adkins, S. W. (2016). What do we really know about alien plant invasion? A review of the invasion mechanism of one of the world's worst weeds. *Planta*, *244*(1), 39-57.

21 Baker, H.G. (1974). The evolution of weeds. Brotherson, J. D., & Field, D. (1987). Tamarix: impacts of a successful weed. *Rangelands Archives, 9(3),* 110-112.

22 Bakke, A. L. (1936). Leafy spurge, *Euphorbia esula* L. *Iowa Agriculture and Home Economics Experiment Station Research Bulletin*, *17*(198), 1.

23 Bala, R., & Kaul, V. (2011). Floral traits in relation to breeding system in *Emex australis* Steinh. *Current Science*, 554-559.

24 Balandrán-Quintana, R.R., González-León, A., Islas-Rubio, A.R., Madera-Santana, T.J., Soto-Valdez, H., Mercado-Ruiz, J.N., Peralta, E., Robles-Osuna, L.E., Vásquez-Lara, F., Carvallo-Ruiz, T., & Granados-Nevarez, M. C .(2018). An overview of Cholla (*Cylindropuntia* spp.) from Sonora, Mexico. *Journal of the Professional Association for Cactus Development*, *20*, 162-177.

25 Baldev, B. (1962). In vitro studies of floral induction on stem apices of *Cuscuta reflexa* Roxb.—a short-day plant. *Annals of Botany*, *26*(2), 173-174.

26 Barbera, G., Inglese, P., & Pimienta-Barrios, E. (Eds.). (1995). *Agro-ecology, cultivation and uses of cactus pear.* 132, 49-58.

27 Baret, S., Maurice, S., Le Bourgeois, T., & Strasberg, D. (2004). Altitudinal variation in fertility and vegetative growth in the invasive plant *Rubus alceifolius* Poiret (Rosaceae), on Réunion island. *Plant Ecology*, *172*(2), 265-273.

28 Bargali, K., & Bargali, S. S. (2009). *Acacia nilotica*: a multipurpose leguminous plant. *Nature and Science, 7(4)*, 11-19.

29 Barney, J. N., Tharayil, N., DiTommaso, A., & Bhowmik, P. C. (2006). The biology of invasive alien plants in Canada. 5. *Polygonum cuspidatum* Sieb. & Zucc.[= *Fallopia japonica* (Houtt.) Ronse Decr.]. *Canadian Journal of Plant Science*, *86*(3), 887-906.

30 Barrett, S. C. (1977). Tristyly in *Eichhornia crassipes* (Mart.) Solms (water hyacinth). *Biotropica*, 230-238.

31 Bassett, I. J., & Crompton, C. W. (1975). The Biology Of Canadian Weeds.: 11. *Ambrosia artemisiifolia* L. and *A. psilostachya* DC. *Canadian Journal of Plant Science*, *55*(2), 463-476.

32 Bebawi, F. F., Campbell, S. D., & Mayer, R. J. (2013). Can competition with pasture be used to manipulate bellyache bush (*Jatropha gossypiifolia* L.) population biology?. *The Rangeland Journal*, *35*(4), 393-401.

33 Bebawi, F. F., Mayer, R. J., & Campbell, S. D. (2005). Flowering and capsule production of bellyache bush (*Jatropha gossypiifolia* L.). *Plant Protection Quarterly*, *20*(4), 129-132.

34 Bebawi, F. F., Mayer, R. J., & Campbell, S. D. (2005). Phenology of bellyache bush (*Jatropha gossypiifolia* L.) in northern Queensland. *Plant Protection Quarterly*, *20*(2), 46-51.

35 Bebawi, F. F., Vitelli, J. S., Campbell, S. D., Vogler, W. D., Lockett, C. J., Grace, B. S., ... & Heard, T. A. (2007). The biology of Australian weeds 47. *Jatropha gossypiifolia* L. *Plant Protection Quarterly*, *22*(2), 42-58.

36 Beckie, H. J., & Francis, A. (2009). The biology of Canadian weeds. 65. *Salsola tragus* L. (Updated). *Canadian journal of plant science*, *89*(4), 775-789.

37 Beck-Pay, S. L. (2012). Optimisation of pollen viability tests for *Acacia podalyriifolia* and two ploidys of *Acacia mearnsii*. *South African journal of botany*, *78*, 285-289.

38 Beerling, D. J., Bailey, J. P., & Conolly, A. P. (1994). *Fallopia japonica* (Houtt.) ronse decraene. *Journal of Ecology*, *82*(4), 959-979.

39 Bell, G. P. (1998). Ecology and management of *Arundo donax*, and approaches to riparian habitat restoration in southern California. In Brock, J. H., Wade, M., Pysek, P., and Green, D. (Eds.): Plant Invasions: Studies from North America and Europe. Blackhuys Publishers, Leiden, The Netherlands, pp. 103-113.

40 Bellanger, S., Guillemin, J. P., & Darmency, H. (2014). Pseudo-self-compatibility in *Centaurea cyanus* L. *Flora-Morphology, Distribution, Functional Ecology of Plants*, *209*(7), 325-331.

41 Bendixen, L. E., & Nandihalli, U. B. (1987). Worldwide distribution of purple and yellow nutsedge (*Cyperus rotundus* and *C. esculentus*). *Weed Technology*, *1*(1), 61-65.

42 Benson, L. (1982). The Cacti of the United States and Canada. Stanford, California, USA: Stanford University Press.

43 Benson, L., & Walkington, D. L. (1965). The southern Californian prickly pears-invasion, adulteration, and trial-by-fire. *Annals of the Missouri Botanical Garden*, *52*(3), 262-273.

44 Berjano, R., Arista, M., Talavera, M., Ariza, M. J., & Ortiz, P. L. (2014). Plasticity and within plant sex-ratio variation in monoecious *Emex spinosa*. *Turkish Journal of Botany*, *38*(2), 258-267.

45 Best, K. F., Bowes, G. G., Thomas, A. G., & Maw, M. G. (1980). The Biology Of Canadian Weeds. 39 *Euphorbia esula* L. *Canadian Journal of Plant Science*, *60*(2), 651-663.

46 Bhatt, J. R., Singh, J. S., Singh, S. P., Tripathi, R. S., & Kohli, R. K. (2011). Invasive alien plants: an ecological appraisal for the Indian Subcontinent (Vol. 1). CABI.

47 Bicknell, R. A. (1997). Isolation of a diploid, apomictic plant of *Hieracium aurantiacum*. *Sexual Plant Reproduction*, *10*(3), 168-172.

48 Binggeli, P. (1998). An Overview of Invasive Woody Plants in the Tropics. In Starr, F., Starr, K., Loope, L., & Maui, H. I. (2003). Morella faya. United States Geological Survey-Biological Resources Division. Haleakala Field Station, Maui, Hawai'i. Acedido em, 3(04), 2014.

49 Binggeli, P. (2003). Introduced and invasive plants. *The Natural History of Madagascar. SM Goodman and JP Benstead (eds.)*, 257-268.

50 Bishop, G. F., & Davy, A. J. (1994). *Hieracium pilosella* L.(*Pilosella officinarum* F. Schultz & Schultz-Bip.). *Journal of Ecology*, *82*(1), 195-210.

51 Bobich, E. G. (2005). Vegetative reproduction, population structure, and morphology of *Cylindropuntia fulgida* var. *mamillata* in a desert grassland. *International Journal of Plant Sciences*, *166*(1), 97-104.

52 Bodle, M. J., Ferriter, A. P., & Thayer, D. D. (1994). The biology, distribution, and ecological consequences of *Melaleuca quinquenervia* in the Everglades. *Everglades: The ecosystem and its restoration*, 341-355.

53 Boggs, K. W., & Story, J. M. (1987). The population age structure of spotted knapweed (*Centaurea maculosa*) in Montana. *Weed Science*, *35*(2), 194-198.

54 Boke, N. H. (1966). Ontogeny and structure of the flower and fruit of *Pereskia aculeata*. *American Journal of Botany*, *53*(6Part1), 534-542.

55 Boland JM (2008). The roles of floods and bulldozers in the break-up and dispersal of *Arundo donax* (Giant Reed). Madrono, 3: 216-222.

56 Bossard, C. & Lichti, R. (2000). *Carduus pycnocephalus*. In Invasive Species Compendium, CABI. https://www.cabi.org/isc/datasheet/11260#111E5ABE-DFA2-46A4-BE3C-7DFB01D9271B

57 Bourchier, R., Hansen, R., Lym, R., Norton, A., Olsen, D., Randall, C. B., ... & Skinner, L. (2006). Biology and Biological Control of Leafy Surface. USDA Forest Health Technology Enterprise Team.

58 Bowers, J. E. (2004). Temporal variation in longevity of *Opuntia engelmannii* (Cactaceae) flowers. *Madroño*, 51(3), 280-286.

59 Boyne, R. L., Harvey, S. P., Dhileepan, K., & Scharaschkin, T. (2013). Variation in leaf morphology of the invasive cat's claw creeper *Dolichandra unguis-cati* (Bignoniaceae). *Australian Journal of Botany*, *61*(6), 419-423.

60 Bräutigam, S., & Greuter, W. (2018). A new treatment of Pilosella for the Euro-Mediterranean flora. *Willdenowia*, *37*(1), 123-138.

61 Bravo, H.H., (1978). Las Cactáceas de México Reyes-Agüero, J. A., & Valiente-Banuet, A. (2006). Reproductive biology of Opuntia: a review. *Journal of arid environments*, *64(4)*, 549-585.

62 Brenan JPM, (1983). Manual on taxonomy of Acacia species. Present taxonomy of four species of Acacia (*A. albida*, *A. senegal*, *A. nilotica*, *A. tortilis*). In Invasive Species Compendium. *Acacia nilotica* (gum arabic tree). https://www.cabi.org/isc/datasheet/2342#CFD46827-CD3D-458C-913B-2D927BB54C39.

63 Briese, D. T. (1990). A new biological control programme against thistles of the genus Onopordum in Australia. In Delfosse, E. D(ed). *Proceedings of the VII International Symposium on Biological Control of Weeds, Rome, Italy*, pp. 155-163. CSIRO Publications.

64 Briese, D. T. (2012). *Heliotropium amplexicaule* Vahl–blue heliotrope. *Biological Control of Weeds in Australia. CSIRO Publishing, Melbourne*, pp. 282-288.

65 Briese, D. T. (2012). *Onopordum acanthium* L.–Scotch thistle *Onopordum illyricum* L.–Illyrian thistle hybrids. In *Julien, MH, McFadyen, R. & Cullen, J*, (eds). Biological control of weeds in Australia. CSIRO publising, pp. 416-424.

66 Briese, D. T., & Zapater, M. (2002). A strategy for the biological control of blue heliotrope (*Heliotropium amplexicaule*). In Jacob, H. S., Doff, J., & Moore, J. H (eds). Thirteenth Australian Weeds Confernece: Weeds: Threats Now and Forever? Perth, Australia, pp. 394-397.

67 Briese, D. T., Pettit, W. J., Swirepik, A., & Walker, A. (2002). A strategy for the biological control of *Onopordum spp*. thistles in south-eastern Australia. *Biocontrol Science and Technology*, *12*(1), 121-136.

68 Brotherson, J. D., & Field, D. (1987). Tamarix: impacts of a successful weed. *Rangelands Archives*, *9*(3), 110-112.

69 Bruce D. P. (2012). *Opuntia oricola*, in Jepson Flora Project (eds.). http://ucjeps.berkeley.edu/eflora/eflora_display.php?tid=35300.

70 Brunel, S. (2011). Pest risk analysis for *Solanum elaeagnifolium* and international management measures proposed. *EPPO Bulletin*, *41*(2), 232-242.

71 Bruun, H. G. (1937). Genetics notes on Linaria, I—II. *Hereditas*, *22*(3), 395-400.

72 Bruzzese, E. (1996). Ecology of *Cirsium vulgate* and *Silybum marianum* in relation to biological control. *Plant Protection Quarterly*, *11*, 245-249.

73 Buchmann, S. L., & Cane, J. H. (1989). Bees assess pollen returns while sonicating *Solanum* flowers. *Oecologia*, *81*(3), 289-294.

74 Burdon, J. J., & Marshall, D. R. (1981). Biological control and the reproductive mode of weeds. *Journal of Applied Ecology*, 649-658.

75 Burdon, J. J., Jarosz, A. M., & Brown, A. H. D. (1988). Temporal patterns of reproduction and outcrossing in weedy populations of *Echium plantagineum*. *Biological Journal of the Linnean Society*, *34*(1), 81-92.

76 Burrell, J. P. (1981). Invasion of coastal heaths of Victoria by *Leptospermum laevigatum* (J. Gaertn.) F. Muell. *Australian Journal of Botany*, *29*(6), 747-764.

77 Butcher, P. A., Bell, J. C., & Moran, G. F. (1992). Patterns of genetic diversity and nature of the breeding system in *Melaleuca alternifolia* (Myrtaceae). *Australian Journal of Botany*, *40*(3), 365-375.

78 Byrne, M. J., Witkowski, E. T. F., & Kalibbala, F. N. (2011). A review of recent efforts at biological control of *Caesalpinia decapetala* (Roth) Alston (Fabaceae) in South Africa. *African Entomology*, *19*(2), 247-257.

79 California Invasive Plant Council (2019). *Centaurea jacea* ssp. pratensis. https://www.cal-ipc.org/plants/profile/centaurea-jacea-ssp-pratensis-profile/.

80 Carey, Jennifer H. (1994). *Gutierrezia microcephala*. In Fire Effects Information System, [Online]. https://www.fs.fed.us/database/feis/plants/shrub/gutmic/all.html.

81 Carter, J. O. (1994). *Acacia nilotica*: a tree legume out of control. *Forage tree legumes in tropical agriculture.*, 338-351.

82 Carter, R. J. (1990). Biology and control of horehound, *Marrubium vulgare*. In Heap, J. W (ed). *Proceeding of the 9th Australian Weeds Conference,* Adelaide, Australia, pp. 382-386.

83 Cavers, P., Qaderi, M., Threadgill, P., & Steel, M. (2011). The Biology Of Canadian Weeds. 147. *Onopordum acanthium* L. *Canadian journal of plant science*, *91*(4), 739-758.

84 Center, T. D., & Overholt, W. A (2012). Classical biological control of air potato in Florida1. University of Florida, IFAS extension. https://bugwoodcloud.org/CDN/floridainvasives/IFAScircularAPB.pdf

85 Chapman, D., Coetzee, J., Hill, M., Hussner, A., Netherland, M., Pescott, O., ... & Tanner, R. (2017). *Pistia stratiotes* L. *EPPO Bulletin*, *47*(3), 537-543.

86 Chavez-Ramirez, F., Wang, X., Jones, K., Hewitt, D., & Felker, P. (1997). Ecological characterization of Opuntia clones in south Texas: implications for wildlife herbivory and frugivory. *Journal of the Professional Association for Cactus Development*, *2*, 9-19.

87 Chaw, S. M., Lin, S. C., & Wang, B. S. (1993). *Tribulus cistoides* L.(Zygophyllaceae): a new record for the flora of Taiwan. *Bot. Bull. Acad. Sin*, *34*, 31-36.

88 Ciesla, W. M. (2002). Invasive insects, pathogens and plants in Western and Pacific Island forests. Report prepared for Western Forestry Leadership Coalition, 2580 Youngfield Street, Lakewood, CO 80215, USA, 120 pp.

89 Clements, D. R., Peterson, D. J., & Prasad, R. (2001). The Biology Of Canadian Weeds. 112. *Ulex europaeus* L. *Canadian Journal of Plant Science*, *81*(2), 325-337.

90 Coetzee, J. A., Hill, M. P., Julien, M. H., Center, T. D., & Cordo, H. A. (2009). *Eichhornia crassipes* (Mart.) Solms–Laub.(Pontederiaceae). *Biological Control of Tropical Weeds using Arthropods.* Cambridge University Press, New York, 183-210.

91 Coleman, J. R. (1989). Embryology and cytogenetics of apomictic hexaploid *Eupatorium odoratum* L.(Compositae). *Revista Brasileira de Genética*, 803-817.

92 Coombs, E. M., Miller, J. C., Andres, L. A., & Turner, C. E. (2008). Biological control of Mediterranean sage (*Salvia aethiopis*) in Oregon. In Julien, M. H., Sforza, R., Bon, M. C., Evans, H. C., Hatcher, P. E., Hinz, H. L., & Rector, B. G. (eds.).*Proceedings of the XII International Symposium on Biological Control of Weeds*, pp. 529-535.

93 Coppens D'Eeckenbrugge, G., Barney, V. E., Moller Jorgensen, P., & Mc Dougal, J. M. (2001). *Passiflora tarminiana*, a new cultivated species of Passiflora subgenus Tacsonia (Passifloraceae). *Novon*, 8-15.

94 Correia, M., Castro, S., & Rodríguez-Echeverría, S. (2015). Reproductive success of *Acacia longifolia* (Fabaceae, Mimosoideae) in native and invasive populations. *Australian Journal of Botany*, *63*(5), 387-391.

95 Correia, M., Castro, S., Ferrero, V., Crisóstomo, J. A., & Rodríguez-Echeverría, S. (2014). Reproductive biology and success of invasive Australian acacias in Portugal. *Botanical Journal of the Linnean Society*, *174*(4), 574-588.

96 Creager, R. A. (1992). Seed germination, physical and chemical control of catclaw mimosa (*Mimosa pigra var. pigra*). *Weed Technology*, *6*(4), 884-891.

97 Crompton, C. W., Hall, I. V., Jensen, K. I. N., & Hildebrand, P. D. (1988). The biology of Canadian weeds. 83. *Hypericum perforatum* L. *Canadian Journal of Plant Science*, 68(1), 149-162.

98 Cronk, Q. C. B., & Fuller, J. L. (1995). Plant invaders: the threat to natural ecosystems. London, UK; Chapman & Hall Ltd.

99 Croxton, M. D., Andreu, M. A., Williams, D. A., Overholt, W. A., & Smith, J. A. (2011). Geographic origins and genetic diversity of air-potato (Dioscorea bulbifera) in Florida. *Invasive Plant Science and Management*, *4*(1), 22-30.

100 Csurhes, S. M. (1998). Miconia calvescens, a potentially invasive plant in Australia's tropical and sub-tropical rainforests. In *Proceedings of the First Regional Conference on M. calvescens Control.* Papeete, Tahiti, French Polynesia. Gouvernement de Polynésie française/University of Hawai'i at Manoa/Centre ORSTOM de Tahiti.

101 Csurhes, S., Markula, A. & Zhou, Y. (2016). Witchweeds- *Striga* spp. https://www.daf.qld.gov.au/__data/assets/pdf_file/0009/67644/Witchweed-risk-assessment.pdf.

102 Cudney, D. W., Orloff, S. B., & Reints, J. S. (1992). An integrated weed management procedure for the control of dodder (*Cuscuta indecora*) in alfalfa (*Medicago sativa*). *Weed Technology*, *6*(3), 603-606.

103 Czarnecka, J., & Kitowski, I. (2010). Seed Dispersal By The Rook *Corvus Frugilegus* L. In Agricultural Landscape- Mechanisms And Ecological Importance. *Polish Journal of Ecology*, *58*(3), 511-523.

104 Dale, I. J. (1981). Parthenium weed in the Americas. *Australian weeds*, *1*(1), 8-14.

105 David S. & John E. E. (2012). *Acacia decurrens*, in Jepson Flora Project (eds.) /eflora/eflora_display.php?tid=11634.

106 Davis, A. R. (1992). Evaluating honey bees as pollinators of virgin flowers of *Echium plantagineum* L.(Boraginaceae) by pollen tube fluorescence. *Journal of Apicultural Research*, *31*(2), 83-95.

107 Dawson, J. H., Musselman, L. J., Wolswinkel, P. I. E. T. E. R., & Dörr, I. (1994). Biology and control of Cuscuta. *Reviews of Weed Science*, *6*, 265-317.

108 Day, M. D., Clements, D. R., Gile, C., Senaratne, W. K., Shen, S., Weston, L. A., & Zhang, F. (2016). Biology and impacts of Pacific Islands invasive species. 13. *Mikania micrantha* Kunth (Asteraceae) 1. *Pacific science*, *70*(3), 257-286.

109 Defreitas, L., Wittmann, M., & Paim, N. R. (1991). Floral Characteristics, Chromosome-number And Meiotic Behavior Of Hybrids Between *Leucaena leucocephala* (2N= 104) And Tetraploid (2N= 104)(Leguminosae). In Harris, S. A., Hughes, C. E., Abbott, R. J., & Ingram, R. (1994). Genetic variation in Leucaena leucocephala (Lam.) de Wit.(Leguminosae: Mimosoidae). *Silvae Gen*, *43*, 2-3.

110 Dehgan, B., & Webster, G. L. (1979). Morphology and infrageneric relationships of the genus Jatropha (Euphorbiaceae) (Vol. 74). Univ of California Press. *In* Bebawi, F. F., & Campbell, S. D. (2002). The response of bellyache bush (*Jatropha gossypiifolia*) plants cut off at different heights and seasonal times. Tropical Grasslands, 36(2), 65-68.

111 del Carmen Mandujano, M., Carrillo-Angeles, I., Martínez-Peralta, C., & Golubov, J. (2010). Reproductive biology of Cactaceae. Ramawat, K. (eds) Desert Plants. Springer, Berlin, Heidelberg.

112 Denisow, B. (2009). Pollen production, flowering and insect visits on *Euphorbia cyparissias* L. and *Euphorbia virgultosa* Klok. *Journal of apicultural research*, *48*(1), 50-59.

113 Dennill, G. B. (1987). The importance of understanding host plant phenology in the biological control of *Acacia longifolia*. *Annals of applied biology*, *111*(3), 661-666.

114 Derstine, K. S., & Tucker, S. C. (1991). Organ initiation and development of inflorescences and flowers of *Acacia baileyana*. *American journal of botany*, *78*(6), 816-832.

115 Desrochers, A. M., Bain, J. F., & Warwick, S. I. (1988). The Biology Of The Canadian Weeds. 89. *Carduus nutans* L. and *Carduus acanthoides* L. *Canadian Journal of Plant Science*, *68*(4), 1053-1068.

116 Diatloff, G. (1964). How far does groundsel seed travel. *Queensland Agricultural Journal*, *90*, 354-356.

117 DiTomaso J.M. & Healy E.A. (2007). Weeds of California and other Western States. In Invasive Species Compendium. *Centaurea iberica*. https://www.cabi.org/isc/datasheet/109132#51D13E34-B997-4D2E-BB77-4C23B9088081.

118 DiTomaso, J. M. (1998). Impact, biology, and ecology of saltcedar (*Tamarix* spp.) in the southwestern United States. *Weed technology*, *12*(2), 326-336.

119 DiTomaso, J. M., Lovich, J., Randall, J., & Kelly, M. (1996). Yellow starthistle: biology and life history. In Lovich, J., Randall, J., & Kelly, M. (eds). *Proceedings of the California Exotic Pest Plant Council Symposium*, Sacramento, CA, California Exotic Pest Plant Council

120 DiTomaso, J.M., G.B. Kyser et al. (2013). Weed Control in natural areas in the Western United States. Weed Research and Information Center, University of Claifornia. 544 pp.

121 Dodge, R. S., Fulé, P. Z., & Hullsieg, C. (2008). Dalmatian toadflax (*Linaria dalmatica*) response to wildfire in a southwestern USA forest. *Ecoscience*, *15*(2), 213-222.

122 Downey, P. O., & Turnbull, I. (2007). The biology of Australian weeds 48. *Macfadyena unguis-cati* (L.) AH Gentry. *Plant Protection Quarterly*, *22*(3), 82.

123 Dray Jr, F. A., & Center, T. D. (1989). Seed production by *Pistia stratiotes* L.(water lettuce) in the United States. *Aquatic Botany*, *33*(1-2), 155-160.

124 Dray, F. A., Bennett, B. C., & Center, T. D. (2006). Invasion history of *Melaleuca quinquenervia* (Cav.) ST Blake in Florida. *Castanea*, *71*(3), 210-226.

125 Dray, F. A., Bennett, B. C., Center, T. D., Wheeler, G. S., & Madeira, P. T. (2004). Genetic Variation in *Melaleuca quinquenervia* Affects the Biocontrol Agent *Oxyops vitiosa1*. *Weed Technology*, *18*(sp1), 1400-1403.

126 Dugdale, T. M., McLaren, D. A., & Conran, J. G. (2015). The biology of Australian weeds 65.'*Tradescantia fluminensis*' Vell. *Plant Protection Quarterly*, *30*(4), 116.

127 Dulberger, R., & Horovitz, A. (1984). Gender polymorphism in flowers of *Silene vulgaris* (Moench) Garcke (Caryophyllaceae). *Botanical Journal of the Linnean Society*, *89*(2), 101-117.

128 Dunn, P. H. (1979). The distribution of leafy spurge (*Euphorbia esula*) and other weedy Euphorbia spp. in the United States. *Weed Science*, *27*(5), 509-516.

129 Ekhator, F., Uyi, O. O., Ikuenobe, C. E., & Okeke, C. O. (2013). The distribution and problems of the invasive alien plant, *Mimosa diplotricha* C. Wright ex Sauvalle (Mimosaceae) in Nigeria. *American Journal of Plant Sciences*, *4*(04), 866.

130 El Ghazali, G. E., Satti, A. M., & Tsuji, S. I. (1997). Intra-specific pollen polymorphism in *Mimosa pigra* (Mimosaceae). *Grana*, *36*(5), 279-283.

131 Ernst, E. (Ed.). (2003). *Hypericum: the genus Hypericum*. CRC Press.

132 Essl, F., Biró, K., Brandes, D., Broennimann, O., Bullock, J. M., Chapman, D. S., ... & Karrer, G. (2015). Biological flora of the British Isles: *Ambrosia artemisiifolia*. *Journal of Ecology*, *103*(4), 1069-1098.

133 Ewel, J. J. (1979). Ecology of *Schinus*.Csurhes, S. M. (1998). *Miconia calvescens*, a potentially invasive plant in Australia’s tropical and sub-tropical rainforests. Proceedings of the First Regional Conference on *M. calvescens* Control. Papeete, Tahiti, French Polynesia. Gouvernement de Polynésie française/University of Hawai’i at Manoa/Centre ORSTOM de Tahiti.

134 Ewel, J. J., Ojima, D. S., Karl, D. A., & DeBusk, W. F. (1982). Schinus in successional ecosystems of Everglades National Park. Csurhes, S. M. (1998). *Miconia calvescens*, a potentially invasive plant in Australia’s tropical and sub-tropical rainforests. *P*roceedings of the First Regional Conference on *M. calvescens* Control. Papeete, Tahiti, *French Polynesia*. Gouvernement de Polynésie française/University of Hawai’i at Manoa/Centre ORSTOM de Tahiti (Vol. 90).

135 Falińska, K. (1997). Life history variation in *Cirsium palustre* and its consequences for the population demography in vegetation succesion. *Acta Societatis Botanicorum Poloniae*, *66*(2), 207-220.

136 Felker, P., & Clark, P. R. (1981). Rooting of mesquite (Prosopis) cuttings. *Rangeland Ecology & Management/Journal of Range Management Archives*, *34*(6), 466-468.

137 Flores-Torres, A., & Montaña, C. (2012). Recruiting mechanisms of *Cylindropuntia leptocaulis* (Cactaceae) in the southern Chihuahuan desert. *Journal of Arid Environments*, *84* , 63-70.

138 Ford, H. A., & Forde, N. (1976). Birds as possible pollinators of *Acacia pycnantha*. *Australian Journal of Botany*, *24*(6), 793-795.

139 Forest, S., Kim, S., & Loope, L. (2003). *Coccinia grandis* Ivy gourd Cucurbitaceae. United States Geological Survey--Biological Resources Division Haleakala Field Station, Maui, Hawai'I.

140 Forman, J., & Kesseli, R. V. (2003). Sexual reproduction in the invasive species *Fallopia japonica* (Polygonaceae). *American journal of botany*, *90*(4), 586-592.

141 Fosberg, F. R. (1965). Revision of Albizia Sect. Pachysperma (Leguminosae-Mimosoideae). *Reinwardtia*, *7*(1), 71-90.

142 Foxcroft, L. C., Rouget, M., Richardson, D. M., & Mac Fadyen, S. (2004). Reconstructing 50 years of Opuntia stricta invasion in the Kruger National Park, South Africa: environmental determinants and propagule pressure. *Diversity and Distributions*, *10*(5-6), 427-437.

143 Francis, J. K. (2004). *Pluchea carolinensis* (Jacq.) G. Don—cure-for-all. *Wildland shrubs of the United States and its territories: thamnic descriptions*, *1*, 577-579.

144 Francis, J. K. (2004). *Sida rhombifolia* L. arrowleaf sida. Wildland Shrubs of the United States and Its Territories: Thamnic Descriptions.

145 Francis, J. K. (2004). Wildland shrubs of the United States and its territories: Thamnic descriptions, Volume 1. *Gen. Tech. Rep. IITF-GTR-26. San Juan, PR: US Department of Agriculture, Forest Service, International Institute of Tropical Forestry; Fort Collins, CO: US Department of Agriculture, Forest Service, Rocky Mountain Research Station. 830 p.*, *26*.

146 Franck, A. R. (2016). Monograph of Harrisia (Cactaceae). *Phytoneuron 2016–85*, 1-159.

147 Friedman, J., & Barrett, S. C. (2008). High outcrossing in the annual colonizing species *Ambrosia artemisiifolia* (Asteraceae). *Annals of Botany*, *101*(9), 1303-1309.

148 Frischknecht, N. C. (1968). Factors influencing halogeton invasion of crested wheatgrass range. *Rangeland Ecology & Management/Journal of Range Management Archives*, *21*(1), 8-12.

149 Froclich, J., Fowler, S., Gianotti, A., Hill, R., Killgore, E., Morin, L., Sugiyama, L., & Winks, C. (1999). Biological control of mist flower (*Ageratina riparia*, Asteraceae) in New Zealand. *Proceedings of the New Zealand Plant Protection Conference*, pp. 6-11.

150 Frost, C. C., & Musselman, L. J. (1980). Clover broomrape (*Orobanche minor*) in the United States. *Weed Science*, *28*(1), 119-122.

151 Fuentes-Ramírez, A., Pauchard, A., Cavieres, L. A., & García, R. A. (2011). Survival and growth of *Acacia dealbata* vs. native trees across an invasion front in south-central Chile. *Forest Ecology and Management*, *261*(6), 1003-1009.

152 Gaertner M., Nottebrock H., Fourie H., Privett S.D.J., Richardson D.M. (2012) Plant invasions, restoration, and economics: perspectives from South African fynbos. *Perspect Plant Ecol Evol Syst* 14, 341–353.

153 Gardner, C. A. (1930). The double gee (*Emex australis*, Steinh.). In Invasive Speciees Compendium. https://www.cabi.org/isc/datasheet/20826#387557A5-4AA9-4226-9712-6CC01723C1AF.

154 Gaskin, J. F., & Littlefield, J. L. (2017). Invasive Russian Knapweed (*Acroptilon repens*) Creates Large Patches Almost Entirely by Rhizomic Growth. *Invasive Plant Science and Management*, *10*(2), 119-124.

155 Gautier, L. (1992). Taxonomy and distribution of a tropical weed: *Chromolaena odorata* (L.) R. King & H. Robinson. *Candollea*, *47*(2), 645-662.

156 Ghadge, A. G., Karmakar, K., Devani, R. S., Banerjee, J., Mohanasundaram, B., Sinha, R. K., ... & Banerjee, A. K. (2014). Flower development, pollen fertility and sex expression analyses of three sexual phenotypes of Coccinia grandis. *BMC plant biology*, *14*(1), 325.

157 Ghisalberti, E. L. (2000). *Lantana camara* L.(verbenaceae). *Fitoterapia*, *71*(5), 467-486.

158 Ghorbel, S., & Nabli, M. A. (1998). Pollen, pistil and their interrelations in *Borago officinalis* and *Heliotropium europaeum* (Boraginaceae). *Grana*, *37*(4), 203-214.

159 Gibot-Leclerc, S., Dessaint, F., Reibel, C., & Le Corre, V. (2013). *Phelipanche ramosa* (L.) Pomel populations differ in life-history and infection response to hosts. *Flora-Morphology, Distribution, Functional Ecology of Plants*, *208*(4), 247-252.

160 Gibot-Leclerc, S., Sallé, G., Reboud, X., & Moreau, D. (2012). What are the traits of *Phelipanche ramosa* (L.) Pomel that contribute to the success of its biological cycle on its host Brassica napus L.?. *Flora-Morphology, Distribution, Functional Ecology of Plants*, *207*(7), 512-521.

161 Gibson, A. C., & Prigge, B. A. (n.d). Tribulus terrestris, Pucture vine. Vascular plants of Williamson County. http://w3.biosci.utexas.edu/prc/K12/pages/Tribulus%20terrestris.html.

162 Gibson, M. R., Richardson, D. M., Marchante, E., Marchante, H., Rodger, J. G., Stone, G. N., ... & Johnson, S. D. (2011). Reproductive biology of Australian acacias: important mediator of invasiveness?. *Diversity and Distributions*, *17*(5), 911-933.

163 Gilbey, D. J. (1974). Emex species in Australia with particular reference to Western Australia. *Journal of the Australian Institute of Agricultural Science*, *40*(2), 114-120.

164 Gilbey, D. J. (1975). The doublegee problem in Western Australia. *Journal of the Department of Agriculture, Western Australia, Series 4, 16*(1), 23-25.

165 Gilbey, D. J., & Weiss, P. W. (1980). The biology of Australian weeds. 4. *Emex australis* Steinh. *Journal of the Australian Institute of Agricultural Sciences*, 46(4), 221-228.

166 Gillett, J. D., Harley, K. L., Kassulke, R. C., & Miranda, H. J. (1991). Natural enemies of *Sida acuta* and *S. rhombifolia* (Malvaceae) in Mexico and their potential for biological control of these weeds in Australia. *Environmental entomology*, *20*(3), 882-888.

167 Gimingham, C. H. (1960). Biological flora of the British Isles. *Calluna salisb*. A monotypic genus. *Calluna vulgaris* (L.) Hull. *Journal of Ecology*, *48*(2), 455-83.

168 Giovanetti, M., Mariotti Lippi, M., Foggi, B., & Giuliani, C. (2015). Exploitation of the invasive *Acacia pycnantha* pollen and nectar resources by the native bee *Apis mellifera*. *Ecological research*, *30*(6), 1065-1072.

169 Githae, E. W. (2018). Status of Opuntia invasions in the arid and semi-arid lands of Kenya. *CAB Reviews*, *13*(3), 1-7.

170 Global Invasive Species Databas. (2019). Species profile: *Clematis vitalba*. http://www.iucngisd.org/gisd/species.php?sc=157.

171 Global Invasive Species Database. (2019). Species profile: *Acacia saligna*. http://www.iucngisd.org/gisd/species.php?sc=1590.

172 Global Invasive Species Database. (2019). Species profile: *Opuntia monacantha*. http://www.iucngisd.org/gisd/species.php?sc=1426.

173 Glyphis, J. P., Milton, S. J., & Siegfried, W. R. (1981). Dispersal of *Acacia cyclops* by birds. *Oecologia*, *48*(1), 138-141.

174 Gorain, M., Charan, S. K., & Ahmed, S. I. (2012). Record of honey bees in pollination of *Acacia nilotica* wild ex del.(Leguminosae, subfamily mimosoidae) in Rajasthan. *J Entomol Res*, *36*(3), 215-218.

175 Gordon, A. J. (2011). Biological control endeavours against Australian myrtle, *Leptospermum laevigatum* (Gaertn.) F. Muell.(Myrtaceae), in South Africa. *African Entomology*, *19*(1), 349-355.

176 Gordon, A. J., & Fourie, A. (2011). Biological control of Hakea sericea Schrad. & JC Wendl. and Hakea gibbosa (Sm.) Cav.(Proteaceae) in South Africa. *African Entomology*, *19*(2), 303-315.

177 Gourlay, A. H., Wittenberg, R., Hill, R. L., Spiers, A. G., & Fowler, S. V. (2000). The biological control programme against *Clematis vitalba* in New Zealand. In Spencer, R. R(ed). *Proceedings of the X international symposium on biological control of weeds,* Montana State University Bozeman, Montana, USA, pp. 799-806.

178 Graham, J., & Jennings, N. (2009). Raspberry breeding. *Breeding Plantation Tree Crops: Temperate Species* (pp. 233-248). Springer, New York.

179 Grant, V., & Grant, K. A. (1979). Pollination of *Opunta basilaris* and *O. littoralis*. *Plant Systematics and Evolution*, *132*(4), 321-325.

180 Grant, V., & Hurd, P. D. (1979). Pollination of the southwestern opuntias. *Plant Systematics and Evolution*, *133*(1-2), 15-28.

181 Groenteman, R. (2013). Prospects for the biological control of tutsan (*Hypericum androsaemum* L.) in New Zealand. In Wu, Y., Johnson, T., Sing, S., Raghu. S., Wheeler, G., Pratt, P., Warner, K., Center, T., Goolsby, J. & Reardon, R (eds). P*roceedings of the XIII International Symposium on Biological Control of Weeds, Waikoloa, Hawaii, USA*, pp. 128-133.

182 Hardy, O. J., & Vekemans, X. (2001). Patterns of allozyme variation in diploid and tetraploid *Centaurea jacea* at different spatial scales. *Evolution*, *55*(5), 943-954.

183 Hardy, O. J., De Loose, M., Vekemans, X., & Meerts, P. (2001). Allozyme segregation and inter-cytotype reproductive barriers in the polyploid complex *Centaurea jacea*. *Heredity*, *87*(2), 136.

184 Hardy, O. J., Vanderhoeven, S. O. N. I. A., De Loose, M., & Meerts, P. (2000). Ecological, morphological and allozymic differentiation between diploid and tetraploid knapweeds (*Centaurea jacea*) from a contact zone in the Belgian Ardennes. *The New Phytologist*, *146*(2), 281-290.

185 Harper, J. L., & Wood, W. A. (1957). *Senecio Jacobaea* L. *Journal of Ecology*, *45*(2), 617-637.

186 Harrod, R. J., & Taylor, R. J. (1995). Reproduction and pollination biology of *Centaurea* and *Acroptilon* species, with emphasis on *C. diffusa*. *Northwest Science*, *69*(2), 97-105.

187 Haynes, R. R. (1988). Reproductive biology of selected aquatic plants. *Annals of the Missouri Botanical Garden*, 805-810.

188 Heard, T. A., Dhileepan, K., Bebawi, F., Bell, K. L., & Segura, R. (2012). *Jatropha gossypiifolia* L.–bellyache bush. *Biological control of weeds in Australia*, 324-333.

189 Henderson, L. (2001). Alien weeds and invasive plants. In Gordon, A. J. (2011). Biological control endeavours against Australian myrtle, *Leptospermum laevigatum* (Gaertn.) F. Muell.(Myrtaceae), in South Africa. African Entomology, 19(1), 349-355.

190 Herrera, J. (1987). Flower and fruit biology in southern Spanish Mediterranean shrublands. *Annals of the Missouri Botanical Garden*, 69-78.

191 Hetz, E., Liersch, R., & Schieder, O. (1993). The ratio of auto-and xenogamy in *Silybum marianum*. *Planta Medica*, *59*(S 1), A702-A702.

192 Hill, M. P., & Hulley, P. E. (2000). Aspects of the phenology and ecology of the South American weed, *Solanum sisymbriifolium*, in the Eastern Cape Province of South Africa. *African Plant Protection*, *6*(2), 53-59.

193 Hill, V. J., & Groves, R. H. (1973). Variation in *Chondrilla juncea* L. in south-eastern Australia. *Australian Journal of Botany*, *21*(1), 113-135.

194 Hoffmann, J. H., & Moran, V. C. (1991). Biological control of *Sesbania punicea* (Fabaceae) in South Africa. *Agriculture, ecosystems & environment*, *37*(1-3), 157-173.

195 Hoffmann, J. H., & Moran, V. C. (1998). The population dynamics of an introduced tree, *Sesbania punicea*, in South Africa, in response to long-term damage caused by different combinations of three species of biological control agents. *Oecologia*, *114*(3), 343-348.

196 Holm L., Doll J., Holm E., Pancho J., Herberger J. (1997). World weeds: natural histories and distribution. Wiley-Blackwell, 1129 pp. In Invasive Species Compendium, CABI. *https://www.cabi.org/isc/datasheet/55561#8F3DAF2E-E5F1-4CDF-859B-0F34C190B792*

197 Holm, L. G., Plucknett, D. L., Pancho, J. V., & Herberger, J. P. (1977). The World's Worst Weeds. Distribution and Biology. Honolulu, Hawaii, USA: University Press of Hawaii. In Invasive Species Compendium, https://www.cabi.org/isc/datasheet/54446#B97963C7-F380-4333-B00C-E664BE9AC0B7.

198 Holtkamp, R. H. (2012). *Cylindropuntia imbricata* (Haw.) FM Knuth-rope pear *Cylindropuntia rosea* (DC.) Backeb.-Hudson pear. *Biocontrol of weeds in Australia*, 198-202.

199 Hong, L., Shen, H., Ye, W. H., Cao, H. L., & Wang, Z. M. (2007). Self-incompatibility in *Mikania micrantha* in South China. *Weed research*, *47*(4), 280-283.

200 Hough-Goldstein J., Lake E., Reardon R., Wu Y. (2008). Biology and biological control of mile-a-minute weed. USDA Forest Service , Forest Health Technology Entreprise Team.

201 Houliston, G. J., & Chapman, H. M. (2001). Sexual reproduction in field populations of the facultative apomict, *Hieracium pilosella*. *New Zealand Journal of Botany*, *39*(1), 141-146.

202 Howard, R. A. (1969). A check list of cultivar names used in the genus *Lantana*. In Invasive Species Compendium. https://www.cabi.org/isc/datasheet/29771#1549A849-FAE6-497E-838A-AEA04A9FFC71.

203 Hrusa, G. F., & Gaskin, J. F. (2008). The *Salsola tragus* complex in California (Chenopodiaceae): characterization and status of *Salsola australis* and the autochthonous allopolyploid *Salsola ryanii* sp. nov. *Madroño*, *55*(2), 113-131.

204 Hunt, J. R., Cousens, R. D., & Knights, S. E. (2008). The biology of Australian weeds 51. *Heliotropium europaeum* L. *Plant Protection Quarterly*, *23*(4), 146.

205 Hussner, A., Champion, P. D., & Francis, R. A. (2012). Myriophyllum aquaticum (Vell.) Verdcourt (parrot feather). *A Handbook of Global Freshwater Invasive Species. London: Taylor & Francis Group*, 103-4.

206 Isely, D. (1971). Legumes of the United States. IV. Mimosa. *The American Midland Naturalist*, *85*(2), 410-424.

207 Jabeen, R., Prentis, P., Anjum, T., & Adkins, S. W. (2015). Genetic structure of invasive weed Parthenium hysterophorus in Australia and Pakistan. *International Journal of Agriculture and Biology*, *17*(2), 327-333.

208 Jacobs, J., & Sing, S. (2008). Ecology and management of diffuse knapweed (*Centaurea diffusa* Lam.). *Invasive Species Technical Note* No. MT-20. Bozeman, MT: US Department of Agriculture, Natural Resources Conservation Service. 12 p.

209 Jacobs, J., Goodwin, K., & Ogle, D. (2009). Plant Guide for rush skeletonweed (*Chondrilla juncea* L.). USDA-Natural Resources Conservation Service, Montana State Office, Bozeman, MT 59715.

210 Jacono, C. C., Richerson, M. M., Morgan,V. H., & Pfingsten, I. A. (2019). *Hydrilla verticillata* (L.f.) Royle: U.S. Geological Survey, Nonindigenous Aquatic Species Database, Gainesville, FL, https://nas.er.usgs.gov/queries/factsheet.aspx?speciesid=6.

211 James, L. F., & Cronin, E. H. (1974). Management practicies to minimize death losses of sheep grazing Halogeton-infested range. *Rangeland Ecology & Management/Journal of Range Management Archives*, *27*(6), 424-426.

212 Johnson, C. (1978). Australian myrtle. *Plant Invaders: Beautiful but Dangerous*, 92-95. *In* Gordon, A. J. (2011). Biological control endeavours against Australian myrtle, *Leptospermum laevigatum* (Gaertn.) F. Muell (Myrtaceae), in South Africa. African Entomology, 19(1), 349-355.

213 Johnson, S. B. (2008). The Biology of Australian Weeds 50. *Lantana montevidensis* (Spreng.) Briq. *Plant Protection Quarterly*, *23*(3), 107.

214 Johnson, S. B., & Lisle, S. D. (2006). The problem with *Lantana montevidensis* (creeping lantana). In Preston, C., Watts, J. H., & Crossman, N.D(eds). *15th Australian Weeds Conference: Managing weeds in a changing climate*, Weed Management Society of South Australia, Torrens Park, South Australia, pp. 727-730.

215 Jordaan, J., & Mantji, T. (2012). Biological control of Cereus jamacaru (queen of the night cactus) in the Thornveld of the Limpopo Province, South Africa. *Grassroots*, *12*, 36-40.

216 Jordano, P. (1984). Seed weight variation and differential avian dispersal in blackberries *Rubus ulmifolius*. *Oikos*, 149-153.

217 Julien, M. H., Skarratt, B., & Maywald, G. F. (1995). Potential geographical distribution of alligator weed and its biological control by *Agasicles hygrophila*. *Journal of Aquatic Plant Management*, *33*(1), 55-60.

218 Kay, Q. O. N. (1969). The origin and distribution of diploid and tetraploid *Tripleurospermum inodorum* (L.) Schultz Bip. *Watsonia*, *7*(3), 130-141.

219 Kay, Q. O. N. (1994). *Tripleurospermum Inodorum* (L.) Schultz Bip. *Journal of Ecology*, *82*(3), 681-697.

220 Kay, S. H., & Haller, W. T. (1982). Evidence for the existence of distinct alligator weed biotypes. *Journal of Aquatic Plant Management*, *20*(1), 37-41.

221 Keep, E. (1968). Incompatibility in Rubus with special reference to *R. idaeus* L. *Canadian Journal of Genetics and Cytology*, *10*(2), 253-262.

222 Keil, D. J., & Ochsmann, J. (2006). *Centaurea*. *In* Invasive Species Compendium. *Centaurea iberica*. https://www.cabi.org/isc/datasheet/109132#51D13E34-B997-4D2E-BB77-4C23B9088081.

223 Kelly, D., & Skipworth, J. P. (1984). Tradescantia fluminensis in a Manawatu (New Zealand) forest: I. Growth and effects on regeneration. *New Zealand journal of botany*, *22*(3), 393-397.

224 Kenneth A. L. (1996). *Hydrilla verticillata* (L.F.) Royle (Hydrocharitaceae), "The Perfect Aquatic Weed". *Castanea,61*(3), 293-304.

225 Khan, M. A., Blackshaw, R. E., & Marwat, K. B. (2009). Biology of milk thistle (*Silybum marianum*) and the management options for growers in north-western Pakistan. *Weed Biology and Management*, *9*(2), 99-105.

226 King County Noxious Weed Control Program (2010). Old Man's Beard, *Clematis vitalba* (Raninculaceae). https://www.nwcb.wa.gov/images/weeds/Old-mans-beard-Clematis-vitalba-control_King.pdf.

227 King, S., Drlik, T., Simon, L. and Quarles, W. (1996). Integrated weed management of gorse. *In* Clements, D. R., Peterson, D. J., & Prasad, R. (2001). The biology of Canadian weeds. 112. *Ulex europaeus* L. *Canadian Journal of Plant Science*, *81(2)*, 325-337.

228 Kinraide, T. B. (1978). The ecological distribution of cholla cactus (*Opuntia imbricata* (Haw.) DC.) in El Paso County, Colorado. *The Southwestern Naturalist*, 117-133.

229 Kleinjan, C. A., & Edwards, P. B. (1999). A reappraisal of the identification and distribution of *Asparagus asparagoides* in southern Africa. *South African Journal of Botany*, *65*(1), 23-31.

230 Klinkhamer, P. G., & De Jong, T. J. (1987). Plant size and seed production in the monocarpic perennial *Cynoglossum officinale* L. *New Phytologist*, *106*(4), 773-783.

231 Klinkhamer, P. G., & De Jong, T. J. (1993). *Cirsium vulgare* (Savi) Ten. (*Carduus lanceolatus* L., *Cirsium lanceolatum* (L.) Scop., non Hill). *Journal of Ecology (Oxford)*, *81*(1), 177-191.

232 Klinkhamer, P. G., De Jong, T. J., & Van Der Meijden, E. (1988). Production, dispersal and predation of seeds in the biennial *Cirsium vulgare*. *The Journal of Ecology*, 403-414.

233 Klugh, K. (1998). Goatsrue, *Galega officinalis*, in Pennsylvania. *Regul. Hortic*, *24*, 25-28.

234 Kosinski, P. (2010). The genus Rubus in the Bardo mts (central sudetes). *Dendrobiology*, *63*.

235 Krischik, V. A., & Denno, R. F. (1990). Patterns of growth, reproduction, defense, and herbivory in the dioecious shrub *Baccharis halimifolia* (Compositae). *Oecologia*, *83*(2), 182-190.

236 Kuniata, L. S. (2009). *Mimosa diplotricha* C. Wright ex Sauvalle (Mimosaceae). In Raman, A., Reddy, G. V. P., & Muniappan, R. (eds). Biological Control of Tropical Weeds Using Arthropods, Cambridge University Press, Cambridge, 247-255.

237 Kuo, Y. L. (2003). Ecological characteristics of three invasive plants (*Leucaena leucocephala*, *Mikania micrantha*, and *Stachytarpheta urticaefolia*) in Southern Taiwan. Taiwan: Food & Fertilizer Technology Center.

238 Kushwaha, V. B., & Maurya, S. (2012). Biological utilities of *Parthenium hysterophorus*. *Journal of Applied and Natural Science*, *4*(1), 137-143.

239 La Rosa, A. M. (1984). The Biology and Ecology of Passiflora mollissima in Hawaii. Technical report. Cooperative National Park Studies Unit, University of Hawaii at Manoa, Department of Botany, p. 168.

240 Ladyman, J. A. (2004). *Opuntia leptocaulis* DC. desert Christmas cactus cactaceae. Wildland Shrubs of the United States and Its Territories: Thamnic Descriptions: Vol 520.

241 Lakshmi, P. V., Raju, A. J. S., Ram, D. J., & Ramana, K. V. (2011). Floral biology, psychophily, anemochory and zoochory in *Chromolaena odorata* (L.) King and HE Robins (Asteraceae). *Biological Sciences-PJSIR*, *54*(1), 1-8.

242 Lam, A. (2002). Invasion of indigenous vegetation in south-western Australia by *Leptospermum Laevigatum* (Gaertn.) F. Muell.(Myrtaceae). In Jacob, H. S., Doff, J., & Moore, J. H (eds). *Thirteenth Australian Weeds Confernece: Weeds: Threats Now and Forever*? Perth, Australia.

243 Lanini, W. T., & Kogan, M. (2005). Biology and management of Cuscuta in crops. *Ciencia e Investigación Agraria*, *32*(3), 127-141.

244 Lawrence, A. A. (2012). *Rubus ulmifolius*, in Jepson Flora Project (eds.). http://ucjeps.berkeley.edu/eflora/eflora_display.php?tid=42265.

245 Lee, W. G., Macmillan, B. H., Partridge, T. R., Lister, R., & Lloyd, K. M. (2001). Fruit features in relation to the ecology and distribution of Acaena (Rosaceae) species in New Zealand. *New Zealand Journal of Ecology*, 17-27.

246 Lemna, W. K., & Messersmith, C. G. (1990). The biology of Canadian weeds. 94. *Sonchus arvensis* L. *Canadian Journal of Plant Science*, *70*(2), 509-532.

247 Lemna, W. K., & Messersmith, C. G. (1990). The biology of Canadian weeds. 94. *Sonchus arvensis* L. *Canadian Journal of Plant Science*, 70(2), 509-532.

248 Lenzi, M., & Orth, A. I. (2012). Mixed reproduction systems in *Opuntia monacantha* (Cactaceae) in Southern Brazil. *Brazilian Journal of Botany*, *35*(1), 49-58.

249 Li, M. M., Yan, Q. Q., Sun, X. Q., Zhao, Y. M., Zhou, Y. F., & Hang, Y. Y. (2014). A preliminary study on pollination biology of three species in Dioscorea (Dioscoreaceae). *Life Sci J*, *11*, 436-444.

250 Lim, T. K. (2012). Opuntia ficus-indica. In Lim, T. K.(ed). *Edible medicinal and non-medicinal plants,* Springer, Dordrecht, pp. 660-682.

251 Lonsdale, W. M. (1993). Rates of spread of an invading species--*Mimosa pigra* in northern Australia. *Journal of Ecology*, 513-521.

252 Lonsdale, W. M., Miller, I. L., & Forno, I. W. (1989). The biology of Australian weeds. 20. *Mimosa pigra*. *Plant Production Quarterly*, *4*(3), 119-131.

253 Lorenzo, P., González, L., & Reigosa, M. J. (2010). The genus Acacia as invader: the characteristic case of *Acacia dealbata* Link in Europe. *Annals of Forest Science*, *67*(1), 101.

254 Lott, M. S., Volin, J. C., Pemberton, R. W., & Austin, D. F. (2003). The reproductive biology of the invasive ferns *Lygodium microphyllum* and *L. japonicum* (Schizaeaceae): implications for invasive potential. *American Journal of Botany*, *90*(8), 1144-1152.

255 Löve, D., & Dansereau, P. (1959). Biosystematic studies on Xanthium: taxonomic appraisal and ecological status. *Canadian Journal of Botany*, *37*(2), 173-208.

256 Lu, H., Shen, J., Sang, W., Zhang, X., & Lin, J. (2008). Pollen viability, pollination, seed set, and seed germination of croftonweed (*Eupatorium adenophorum*) in China. *Weed science*, *56*(1), 42-51.

257 Lumpkin, T. A., & Plucknett, D. L. (1982). *Azolla as a green manure: use and management in crop production*. Westview Press, Inc..

258 Lutzow-Felling, C. J., Gardner, D. E., Markin, G. P., & Smith, C. W. (1995). *Myrica faya*: review of the biology, ecology, distribution, and control, including an annotated bibliography. Honolulu (HI): Cooperative National Park Resources Studies Unit, University of Hawaii at Manoa, Department of Botany. PCSU Technical Report, 94.

259 Lynes, B. C., & Campbell, S. D. (2000). Germination and viability of mesquite (*Prosopis pallida*) seed following ingestion and excretion by feral pigs (*Sus scrofa*). *Tropical Grasslands*, *34*(2), 125-128.

260 Maddox, D. M., Mayfield, A., Joley, D. B., & Supkoff, D. M. (1996). Pollination biology of yellow starthistle (*Centaurea solstitialis*) in California. *Canadian Journal of Botany*, *74*(2), 262-267.

261 Madire, L. G., Wood, A. R., Williams, H. E., & Neser, S. (2011). Potential agents for the biological control of *Tecoma stans* (L.) Juss ex Kunth var. stans (Bignoniaceae) in South Africa. *African Entomology*, *19*(1), 434-442.

262 Mahy, G., & Jacquemart, A. L. (1998). Mating system of *Calluna vulgaris*: self-sterility and outcrossing estimations. *Canadian Journal of Botany*, *76*(1), 37-42.

263 Mahy, G., Sloover, J. D., & Jacquemart, A. L. (1998). The generalist pollination system and reproductive success of *Calluna vulgaris* in the Upper Ardenne. *Canadian Journal of Botany*, *76*(11), 1843-1851.

264 Mai, T. R., Lovett-Doust, J., Lovett-Doust, L., & Mulligan, G. A. (1992). The biology of Canadian weeds. 100. *Lythrum salicaria*. *Canadian Journal of Plant Science*, *72*(4), 1305-1330.

265 Makepeace, W. (1985). Growth, reproduction, and production biology of mouse-ear and king devil hawkweed in eastern South Island, New Zealand. *New Zealand Journal of Botany*, *23*(1), 65-78.

266 Malik, N., & Born, W. H. V. (1987). Growth and development of false cleavers (*Galium spurium* L.). *Weed Science*, *35*(4), 490-495.

267 Malik, N., & Born, W. V. (1988). The biology of Canadian weeds.: 86. *Galium aparine* L. and *Galium spurium* L. *Canadian Journal of Plant Science*, *68*(2), 481-499.

268 Mallory-Smith, C., & Colquhoun, J. (2012). Small broomrape (*Orobanche minor*) in Oregon and the 3 Rs: regulation, research, and reality. *Weed science*, *60*(2), 277-282.

269 Marchante, H., Freitas, H., & Hoffmann, J. H. (2010). Seed ecology of an invasive alien species, *Acacia longifolia* (Fabaceae), in Portuguese dune ecosystems. *American journal of botany*, *97*(11), 1780-1790.

270 Maroyi, A. (2016). *Cylindropuntia fulgida* (Engelm.) FM Knuth var. *fulgida* (Cactaceae) is naturalised and spreading in Zimbabwe. *Bradleya*, *2016*(34), 24-28.

271 Mártonfi, P., Brutovská, R., Ĉellárová, E., & Repĉák, M. (1996). Apomixis and hybridity in *Hypericum perforatum*. *Folia Geobotanica*, *31*(3), 389-396.

272 Mathur, G., & Ram, H. M. (1986). Floral biology and pollination of *Lantana camara*. *Phytomorphology*, *36*(1/2), 79-100.

273 McAuley, M. (2017). Prickly pear. Wildflowers of the Santa Monica Mountains. Flowering Plants: The Santa Monica Mountains, Coastal and Chaparral Regions of Southern California. https://smmtc.org/plantofthemonth/Prickly_Pear.php.

274 McCarty, L. B., Colvin, D. L., & Higgins, J. M. (1996). Highbush blackberry (*Rubus argutus*) control in bahiagrass (*Paspalum notatum*). *Weed technology*, *10*(4), 754-761.

275 McCauley, D. E., & Brock, M. T. (1998). Frequency-dependent fitness in *Silene vulgaris*, a gynodioecious plant. *Evolution*, *52*(1), 30-36.

276 McConnachie, A. J., De Wit, M. P., Hill, M. P., & Byrne, M. J. (2003). Economic evaluation of the successful biological control of *Azolla filiculoides* in South Africa. *Biological control*, *28*(1), 25-32.

277 McFadyen, R. E. (1979). The cactus mealybug *Hypogeococcus festerianus* [Hem.: Pseudococcidae] an agent for the biological control of *Eriocereus martinii* [Cactaceae] in Australia. *Entomophaga*, *24*(3), 281-287.

278 McFadyen, R. E. (2012). Harrisia (Eriocereus) martinii (Labour.) Britton—Harrisia cactus *Acanthocereus tetragonus* (L.) Hummelink—sword pear. *Biological control of weeds in Australia*, 274-281.

279 McFarland, J. D., Kevan, P. G., & Lane, M. A. (1989). Pollination biology of *Opuntia imbricata* (Cactaceae) in southern Colorado. C*anadian Journal of Botany*, *67*(1), 24-28.

280 McVean, D. N. (1966). Ecology of *Chondrilla juncea* L. in south-eastern Australia. *The Journal of Ecology*, 345-365.

281 Medal, J. C., Gandolfo, D., Pitelli, R. A., Santana, A., Cuda, J. P., & Sudbrink, D. L. (1999, July). Progress and prospects for biological control of *Solanum viarum* Dunal in the USA. In Spencer, N. R(ed). *Proceedings of the X International Symposium on Biological Control of Weeds*, Montana State University, Bzeman, Montana, USA, pp. 627-631.

282 Melastome, A., Starr, F., Starr, K., Loope, L., & Maui, H. I. (2003). *Melastoma candidum*. http://www.hear.org/PIER/pdf/pohreports/melastoma_candidum.pdf

283 Meyer, J. Y. (1998). Observations on the reproductive biology of *Miconia calvescens* DC (Melastomataceae), an alien invasive tree on the Island of Tahiti (South Pacific Ocean) 1. *Biotropica*, *30*(4), 609-624.

284 Meyer, K. (2001). Revision of the Southeast Asian genus Melastoma. *Blumea*, *46*(2), 351-398.

285 Michaux, B. (1989). Reproductive and vegetative biology of *Cirsium vulgare* (Savi) Ten.(Compositae: Cynareae). *New Zealand Journal of Botany*, *27*(3), 401-414.

286 Millar, M. A., Coates, D. J., Byrne, M., Krauss, S. L., Jonson, J., & Hopper, S. D. (2019). Assessment of genetic diversity and mating system of *Acacia cyclops* restoration and remnant populations. *Restoration Ecology*, *27*(6), 1327-1338.

287 Miller, A. (1984). The distribution and ecology of Buddleja davidii Franch in Britain, with particular reference to conditions supporting germination and the establishment of seedlings. Dissertation, CNAA, Oxford Polytechnic.

288 Milton, S. J., & Hall, A. V. (1981). Reproductive biology of Australian acacias in the south-western Cape Province, South Africa. *Transactions of the Royal Society of South Africa*, *44*(3), 465-487.

289 Misset, M. T., & Gourret, J. P. (1996). Flow cytometric analysis of the different ploidy levels observed in the genus *Ulex* L. Faboideae-Genisteae in Brittany (France). *Botanica Acta*, *109*(1), 72-79.

290 Mitchell, D. S., Petr, T., & Viner, A. B. (1980). The water-fern Salvinia molesta in the Sepik River, Papua New Guinea. *Environmental Conservation*, *7*(2), 115-122.

291 Moffett, A. A., & Nixon, K. M. (1974). The effects of self-fertilization on Green Wattle (*Acacia decurrens* Willd.) and Black Wattle (*Acacia mearnsii* De Wild.), 66-84.

292 Montagnani, C., Gentili, R., Smith, M., Guarino, M. F., & Citterio, S. (2017). The worldwide spread, success, and impact of ragweed (*Ambrosia spp.*). *Critical reviews in plant sciences*, *36*(3), 139-178.

293 Moore, A. W. (1969). Azolla: biology and agronomic significance. *The Botanical Review*, *35*(1), 17-34.

294 Moore, R. J. (1975). The biology of Canadian weeds.: 13. *Cirsium arvense* (L.) Scop. *Canadian Journal of Plant Science*, *55*(4), 1033-1048.

295 Moore, R. J. (1975). The *Galium aparine* complex in Canada. *Canadian Journal of Botany*, *53*(9), 877-893.

296 Moore, R. J., & Lindsay, D. R. (1953). Fertility and polyploidy of *Euphorbia cyparissias* in Canada. *Canadian Journal of Botany*, *31*(2), 152-163.

297 Moran, G. F., & Marshall, D. R. (1978). AlIozyme uniformity within and variation between races of the colonizing species *Xanthium Strumarium* L. (Noogoora Burr). *Australian Journal of Biological Sciences*, *31*(3), 283-292.

298 Moran, V. C., Zimmermann, H. G., & Annecke, D. P. (1976). The identity and distribution of *Opuntia aurantiaca* Lindley. *Taxon*, 281-287.

299 Morgan, A., Carthew, S. M., & Sedgley, M. (2002). Breeding system, reproductive efficiency and weed potential of *A. baileyana*. *Australian Journal of Botany*, *50*(3), 357-364.

300 Morin, L., Batchelor, K. L., & Scott, J. K. (2006). The biology of Australian weeds 44. *Asparagus asparagoides* (L.) Druce. *Plant Protection Quarterly*, *21*(2), 46-62.

301 Mountain, W. L. (1989). Mile-a-minute (*Polygonum perfoliatum* L.) update—distribution, biology, and control suggestions. *Regulatory Horticulture*, *15*, 21-24.

302 Mulcahy, D. L. (1975). The reproductive biology of *Eichhornia crassipes* (Pontederiaceae). *Bulletin of the Torrey Botanical Club*, 18-21.

303 Mullahey, J. J., & Cornell, J. (1994). Biology of tropical soda apple (*Solanum viarum*) an introduced weed in Florida. *Weed Technology*, *8*(3), 465-469.

304 Mullin, B. H. (1998). The biology and management of purple loosestrife (*Lythrum salicaria*). *Weed Technology*, *12*(2), 397-401.

305 Muniappan, R., Reddy, G. V. P., & Raman, A. (2009). *Coccinia grandis* (L.) Voigt (Cucurbitaceae). In Muniappan, R., Reddy, G. V., & Raman, A. (Eds.). Biological control of tropical weeds using arthropods. Cambridge University Press, New York, USA, 175-182.

306 Muniappan, R., Reddy, G. V., & Raman, A. (Eds.). (2009). *Biological control of tropical weeds using arthropods*. Cambridge University Press.

307 Munoz-Urias, A., Palomino-Hasbach, G., Huerta-Martinez, F. M., Pimienta Barrios, E., & Ramírez-Hernánez, B. C. (2006). Reproductive isolation in fragmented wild populations of *Opuntia streptacantha*. *Journal of the Professional Association for Cactus Development*, *8*, 26-38.

308 Nadeau, L. B., & King, J. R. (1991). Seed dispersal and seedling establishment of *Linaria vulgaris* Mill. *Canadian Journal of Plant Science*, *71*(3), 771-782.

309 Negi, G. C., Sharma, S., Vishvakarma, S. C., Samant, S. S., Maikhuri, R. K., Prasad, R. C., & Palni, L. M. (2019). Ecology and Use of *Lantana camara* in India. *The Botanical Review*, *85*(2), 109-130.

310 Nerd, A., & Mizrahi, Y. (1997). Reproductive biology of cactus fruit crops. *Horticultural Reviews*, *18*, 321-346.

311 Neser, S., & Kluge, R. L. (1986). importance of seed-attacking agents in the biological control of invasive alien plants. In Macdonald, L. A. W., Kruger, F. J., & Ferrar, A. A(eds). *Ecology and management of biological invasions in southern Africa: proceedings of the National Synthesis Symposium on the Ecology of Biological Invasions.*

312 Nolan, D. G., & Upadhyaya, M. K. (1988). Primary seed dormancy in diffuse and spotted knapweed. *Canadian Journal of Plant Science*, *68*(3), 775-783.

313 Nosratti, I., Abbasi, R., Bagheri, A., & Bromandan, P. (2017). Seed germination and seedling emergence of *Iberian starthistle* (*Centaurea iberica*). *Weed biology and management*, *17*(3), 144-149.

314 O'Donnell, C., & Tyler, R. (2002). *The creeping Lantana handbook: A guide to ecology, control and management*. Department of Primary Industries. *In* Johnson, S. B. (2008). The Biology of Australian Weeds 50. *Lantana montevidensis* (Spreng.) Briq. *Plant Protection Quarterly*, 23(3), 107.

315 Oliver, J. D. (1993). A review of the biology of giant salvinia. *Journal of Aquatic Plant Management*, 31, 227-231.

316 Olivieri, I., Swan, M., & Gouyon, P. H. (1983). Reproductive system and colonizing strategy of two species of Carduus (Compositae). *Oecologia*, *60*(1), 114-117.

317 Olvera-Carrillo, Y., Márquez-Guzmán, J., Sánchez-Coronado, M. E., Barradas, V. L., Rincón, E., & Orozco-Segovia, A. (2009). Effect of burial on the germination of *Opuntia tomentosa's* (Cactaceae, Opuntioideae) seeds. *Journal of Arid Environments*, *73*(4-5), 421-427.

318 Opler, P. A., Baker, H. G., & Frankie, G. W. (1975). Reproductive biology of some Costa Rican Cordia species (Boraginaceae). *Biotropica*, 234-247.

319 Pande, P. C., & Joshi, G. C. (1984). *Opuntia elatior* Mill-an epiphyte on *Cedrus deodara* (Roxb. ex Lam) G. Don and *Celtis eriocarpa* Decaisne. *Indian Journal of Forestry*, *7*(2), 161-162.

320 Parker, C., & Riches, C. R. (1993). Parasitic weeds of the world: biology and control. Wallingford, UK; CAB International.

321 Parker, I. M. (1997). Pollinator limitation of *Cytisus scoparius* (Scotch broom), an invasive exotic shrub. *Ecology*, *78*(5), 1457-1470.

322 Parsons, W. T., & Cuthbertson, E. G. (1992). Noxious Weeds of Australia, Inkata Press, Melbourne/Sydney.

323 Parsons, W. T., Parsons, W. T., & Cuthbertson, E. G. (2001). *Noxious weeds of Australia*. CSIRO publishing.

324 Pasiecznik, N. M., Felker, P., Harris, P. J., Harsh, L., Cruz, G., Tewari, J. C., ... & Maldonado, L. J. (2001). *The'Prosopis Juliflora'-'Prosopis Pallida'Complex: A Monograph*. Coventry: HDRA.

325 Pasta, S., Badalamenti, E., & La Mantia, T. (2012). *Acacia cyclops* A. Cunn. ex G. Don (Leguminosae) in Italy: first cases of naturalization. In *Anales del Jardín Botánico de Madrid*, 69(2), 193-200.

326 Patel, H. D., Harisha, C. R., Acharya, R., & Jani, S. (2016). Micromorphological and micrometric evaluation of *Opuntia elatior* Mill. Flower.

327 Patel, S., Sharma, V., Chauhan, N. S., & Dixit, V. K. (2012). An updated review on the parasitic herb of *Cuscuta reflexa* Roxb. *Journal of Chinese Integrative Medicine*, *10*(3), 249-255.

328 Pelton, J. (1964). A survey of the ecology of Tecoma stans. *Butler University Botanical Studies*, 53-88.

329 Pemberton, R. W., & Ferriter, A. P. (1998). Old World climbing fern (*Lygodium microphyllum*), a dangerous invasive weed in Florida. *American Fern Journal*, 165-175.

330 Penfound, W. T., & Earle, T. T. (1948). The biology of the water hyacinth. *Ecological Monographs*, *18*(4), 447-472.

331 Peng, C. I., Chen, C. H., Leu, W. P., & Yen, H. F. (1998). Pluchea Cass.(Asteraceae: Inuleae) in Taiwan. *Botanical Bulletin of Academia Sinica*, *39*.

332 Peterson, D. J., & Prasad, R. (1998). The biology of Canadian weeds. 109. *Cytisus scoparius* (L.) Link. *Canadian journal of plant science*, *78*(3), 497-504.

333 Pettersson, M. W. (1991). Flower herbivory and seed predation in *Silene vulgaris* (Caryophyllaceae): effects of pollination and phenology. *Ecography, 14*(1), 45-50.

334 Piggin, C. M. (1978). Dispersal of *Echium plantagineum* L. by sheep. *Weed Research*, *18*(3), 155-160.

335 Pilu, R., Badone, F. C., & Michela, L. (2012). Giant reed (*Arundo donax* L.): A weed plant or a promising energy crop? *African Journal of Biotechnology*, *11*(38), 9163-9174.

336 Pinkava, D. J. (1999). Cactaceae Cactus Family: Part Three: Cylindropuntia (Engelm.) Knuth Chollas. *Journal of the Arizona-Nevada Academy of Science*, 32-47.

337 Pitcairn, M. J., Young, J. A., Clements, C. D., & Balciunas, J. O. E. (2002). Purple starthistle (*Centaurea calcitrapa*) seed germination. *Weed Technology*, *16*(2), 452-456.

338 Poindexter, D. B. (2010). *Persicaria perfoliata* (Polygonaceae) reaches North Carolina. *Phytoneuron*, *30*, 1-9.

339 Porter, D. M. (1971). Notes on the floral glands in Tribulus (Zygophyllaceae). *Annals of the Missouri Botanical Garden*, 1-5.

340 Prajapati, S., & Acharya, R. (2015). *Opuntia elatior* Mill.(Nagaphani): A Review on its Ethnobotany, Phytochemical and Pharmacological Properties. *Ann. Ayurvedic Med.*, *4*, 107-116.

341 Prentis, P. J., Sigg, D. P., Raghu, S., Dhileepan, K., Pavasovic, A., & Lowe, A. J. (2009). Understanding invasion history: genetic structure and diversity of two globally invasive plants and implications for their management. *Diversity and Distributions*, *15*(5), 822-830.

342 Prider, J. (2015). The reproductive biology of the introduced root holoparasite *Orobanche ramosa* subsp. *mutelii* (Orobanchaceae) in South Australia. *Australian Journal of Botany*, *63*(5), 426-434.

343 Qaderi, M. M. (1998). *Intraspecific variation in germination of Scotch thistle (Onopordum acanthium L.) cypselas*. *In* Invasive Species Compendium. Onopordum acanthium. https://www.cabi.org/isc/datasheet/37456#61AA27BC-C35A-4D80-AD0F-8FE001CE31A5.

344 Quinn, J. A. (1974). Convolvulus sepium in old field succession on the New Jersey Piedmont. *Bulletin of the Torrey Botanical Club*, 89-95.

345 Raju, A. S., & Rani, D. S. (2016). Pollination ecology of *Sida acuta*, *S. cordata* and *S. cordifolia* (Malvaceae). *Phytologia Balcanica: International Journal of Balkan Flora and Vegetation*, *22*(3), 363-376.

346 Raju, B. M., Ganeshaiah, K. N., & Shaanker, R. U. (2001). Paternal parents enhance dispersal ability of their progeny in a wind-dispersed species, *Tecoma stans* L. *Current Science*, *81*(1), 22-24.

347 Ramakrishnan, P. S. (1969). Nutritional factors influencing the distribution of the calcareous and acidic populations in *Hypericum perforatum*. *Canadian Journal of Botany*, *47*(1), 175-181.

348 Rambuda, T. D., & Johnson, S. D. (2004). Breeding systems of invasive alien plants in South Africa: does Baker's rule apply? *Diversity and Distributions*, *10*(5-6), 409-416.

349 Randall, J. M. (2000). *Centaurea calcitrapa*. In Pitcairn, M. J., Young, J. A., Clements, C. D., & Balciunas, J. O. E. (2002). Purple starthistle (*Centaurea calcitrapa*) seed germination. *Weed Technology, 16(2),* 452-456.

350 Raymond, K. L. (1999). *Ecology of Asparagus asparagoides (bridal creeper): an environmental weed of southern Australia*. *In* Morin, L., Batchelor, K. L., & Scott, J. K. (2006). The biology of Australian weeds 44. *Asparagus asparagoides* (L.) Druce. *Plant Protection Quarterly*, 21(2), 46-62.

351 Reddi, E. U. B., & Reddi, C. S. (1983). Pollination ecology of J*atropha gossypiifolia* (Euphorbiaceae). *Proceedings of Indian Acdemy of Science.*

352 Rendell, S., & Ennos, R. A. (2002). Chloroplast DNA diversity in *Calluna vulgaris* (heather) populations in Europe. *Molecular Ecology*, *11*(1), 69-78.

353 Renner, S. S. (1989). A survey of reproductive biology in Neotropical Melastomataceae and Memecylaceae. *Annals of the Missouri Botanical Garden*, 496-518.

354 Renoult, J. P., Thomann, M., Schaefer, H. M., & Cheptou, P. O. (2013). Selection on quantitative colour variation in *Centaurea cyanus*: the role of the pollinator's visual system. *Journal of Evolutionary Biology*, *26*(11), 2415-2427.

355 Reyes-Agüero, J. A., & Valiente-Banuet, A. (2006). Reproductive biology of Opuntia: a review. *Journal of arid environments*, *64*(4), 549-585.

356 Richardson, D. M., Van Wilgen, B. W., & Mitchell, D. T. (1987). Aspects of the reproductive ecology of four Australian Hakea species (Proteaceae) in South Africa. *Oecologia*, *71*(3), 345-354.

357 Roche Jr, B. F. (1992). Achene dispersal in yellow starthistle (*Centaurea solstitialis* L.). *Northwest Science*, *66*(2), 62-65.

358 Roche, C. (1991). Silverleaf Nightshade (*Solanum elaeagnifolium* Cav.) Pacific Northwest Extension Publication 365. *Washington State University, US*.

359 Roche, C. (1999). Squarrose knapweed. The Identification, Distribution, Impacts, Biology and Management of Noxious Rangeland Weeds, 347.

360 Roché, C. T. (1991). Weeds--Milk Thistle (*Silybum Marianum* (L.) Gaertn.). Washington State University Extension Service.

361 Roché, C. T., & Burrill, L. C. (1994). Squarrose knapweed, *Centaurea virgat*a Lam. ssp. squarrosa Gugl. Technical report. Oregon State University Extension Service.

362 Roché, C. T., Roché Jr, B. F., & Rasmussen, G. A. (1992). Dispersal of squarrose knapweed (*Centaurea virgata ssp. squarrosa*) capitula by sheep on rangeland in Juab County, Utah. *Great Basin Naturalist*, *52*(2), 12.

363 Roche, C., & Burrill, L. C. (1992). Slenderflower thistle (*Carduus tenuiflorus* Curt.) Italian thistle (*Carduus pycnocephalus* L.) plumeless thistle (*Carduus acanthoides* L.). *PNW (USA)*.

364 Rodríguez-Estrella, R., Navarro, J. J. P., Granados, B., & Rivera, L. (2010). The distribution of an invasive plant in a fragile ecosystem: the rubber vine (*Cryptostegia grandiflora*) in oases of the Baja California peninsula. *Biological Invasions*, *12*(10), 3389-3393.

365 Rousseau, J. & Loiseau, A. (1982) Structure et cycle de development des peuplements a '*Cytisus scoparius* L.' dans le chaine des puys. *In* Sheppard, A. W., Hodge, P., Paynter, Q., & Rees, M. (2002). Factors affecting invasion and persistence of broom Cytisus scoparius in Australia. *Journal of Applied Ecology, 39(5)*, 721-734.

366 Rueda, R. M. (1993). The genus *Clerodendrum* (Verbenaceae) in Mesoamerica. *Annals of the Missouri Botanical Garden*, 870-890.

367 Sagliocco, J. L., & Coupland, J. B. (1995). Biology and host specificity of *Chamaesphecia mysiniformis* (Lepidoptera: Sesiidae), a potential biological control agent of *Marrubium vulgare* (Lamiaceae) in Australia. *Biocontrol science and technology*, *5*(4), 509-516.

368 Saha, M., & Datta, B. K. (2014). Reproductive biology of Solanum viarum Dunal (Solanaceae) in Northeast India. *East Himalayan Society for Spermatophyte Taxonomy*, *8*(2), 258-266.

369 Saltonstall, K., Lambert, A., & Meyerson, L. A. (2010). Genetics and reproduction of common (*Phragmites australis*) and giant reed (*Arundo donax*). *Invasive Plant Science and Management*, *3*(4), 495-505.

370 Sampson, A. W. and K. W. Parker. (1930). St. Johns-wort on rangelands of California. *In* Crompton, C. W., Hall, I. V., Jensen, K. I. N., & Hildebrand, P. D. (1988). The biology of Canadian weeds. 83. *Hypericum perforatum* L. *Canadian Journal of Plant Science*, 68(1), 149-162.

371 Saner, M. A., Clements, D. R., Hall, M. R., Doohan, D. J., & Crompton, C. W. (1995). The biology of Canadian weeds. 105. *Linaria vulgaris* Mill. *Canadian Journal of Plant Science*, *75*(2), 525-537.

372 Scheinvar, L. (2002). *Opuntia stricta* (Haw.) Haw. ssp. esparzae, a new subspecies of the dunes of rio Concá, Arroyo Seco, Querétaro, Mexico. *Cactáceas y Suculentas Mexicanas*, *47*(4), 94-102.

373 Scheinvar, L., & Fuentes, A. R. (2003). Nueva subespecie de *Opuntia streptacantha* (Cactaceae) de la altiplanicie mexicana. *Anales del Instituto de Biología. Serie Botánica*, *74*(2), 303-311.

374 Schooler, S., Palmer, B., & Morin, L. (2012). *Ageratina riparia* (Regel) K. & R.– mistflower. In Cullen, J., Julien, M. H & McFadyen, R. E (eds). Biological control of weeds in Australia. CSIRO, Melbourne, pp. 33-42.

375 Schultz, G. E. (1993). Element Stewardship abstract for Dioscorea bulbifera Air potato. Control methods--plants. In: Global Invasive Species Team (GIST). Arlington, VA: The Nature Conservancy. http://www. invasive. org/gist/esadocs/documnts/diosbul. pdf.

376 Schürch, S., Pfunder, M., & Roy, B. A. (2000). Effects of ants on the reproductive success of *Euphorbia cyparissias* and associated pathogenic rust fungi. *Oikos*, *88*(1), 6-12.

377 Scott, L. (2008). Puncturevine (*Tribulus terrestris*). Invasive plants of the Okanagan-Similkameen. http://www.rdosmaps.bc.ca/min_bylaws/legislative_services/weed_control/FACTSHEET_PV_FINAL_Feb_2008.pdf.

378 Searle, S. D. (1997). *Acacia mearnsii* De Wild.(black wattle) in Australia. *Black Wattle and its utilization. Barton: ACT*, 1-10.

379 Sedgley, M. (1986). Reproductive biology of acacias. Turnbull, J. W. (ed). Australian Acacias in Developing Countries. ACIAR Proceedings, (16), 54-56.

380 Sell, P.D. & Murrell, J.G. (2006) Flora of Great Britain and Ireland. *In* Tiley, G. E. (2010). Biological Flora of the British Isles: *Cirsium arvense* (L.) Scop. *Journal of Ecology*, 98(4), 938-983.

381 Senatore, F., Landolfi, S., Celik, S., & Bruno, M. (2006). Volatile components of *Centaurea calcitrapa* L. and *Centaurea sphaerocephala* L. ssp. *sphaerocephala*, two Asteraceae growing wild in Sicily. *Flavour and fragrance journal*, *21*(2), 282-285.

382 Sheley, R. L., Hudak, J. M., Grubb, R. T., & Petroff, J. K. (1999). Rush skeletonweed. *The Identification, Distribution, Impacts, Biology and Management of Noxious Rangeland Weeds*, 317.

383 Sheley, R. L., Jacobs, J. S., & Carpinelli, M. F. (1998). Distribution, biology, and management of diffuse knapweed (*Centaurea diffusa*) and spotted knapweed (*Centaurea maculosa*). *Weed Technology*, *12*(2), 353-362.

384 Shiferaw, H., Teketay, D., Nemomissa, S., & Assefa, F. (2004). Some biological characteristics that foster the invasion of *Prosopis juliflora* (Sw.) DC. at Middle Awash Rift Valley Area, north-eastern Ethiopia. *Journal of Arid environments*, *58*(2), 135-154.

385 Simpson, D., & Sanderson, H. (2002). 434. *Epichhornia crassipes*: Pontederiaceae. *Curtis's botanical magazine*, 28-34.

386 Sims-Chilton, N. M., & Panetta, F. (2011). The biology of Australian weeds 58. *Baccharis halimifolia* L. *Plant Protection Quarterly*, *26*(4), 114.

387 Sinha, S. C. (1971). Floral morphology of acacias. *In* Sedgley, M., & Harbard, J. (1993). Pollen storage and breeding system in relation to controlled pollination of four species of Acacia (Leguminosae: Mimosoideae). *Australian Journal of Botany*, *41(5*), 601-609.

388 Skarpaas, O., & Shea, K. (2007). Dispersal patterns, dispersal mechanisms, and invasion wave speeds for invasive thistles. *The American Naturalist*, *170*(3), 421-430.

389 Smith, C. A., Shaw, D. R., & Newsom, L. J. (1992). Arrowleaf sida (*Sida rhombifolia*) and prickly sida (*Sida spinosa*): germination and emergence. *Weed Research*, *32*(2), 103-109.

390 Smith, C. W. (1992). Distribution, status, phenology, rate of spread, and management of Clidemia in Hawaii. Alien plant invasions in native ecosystems of Hawaii: management and research. University of Hawaii Cooperative National Park Resources Studies Unit, Honolulu, 241-253.

391 Smith, G. F., & Figueiredo, E. (2012). South Africa's ongoing *Opuntia mill*.(Cactaceae) problem: the case of *Opuntia tomentosa Salm-Dyck*. *Bradleya*, *2012*(30), 61-65.

392 Smith, L. M., & Kok, L. T. (1984). Dispersal of musk thistle (*Carduus nutans*) seeds. *Weed science*, *32*(1), 120-125.

393 Sosa, A. J., Julien, M. H., & Cordo, H. A. (2004). New research on *Alternanthera philoxeroides* (alligator weed) in its South American native range. In Cullen, J. M., Briese, D. T., Kriticos, D. J., Lonsdale, W. M., Morin, L., & Scott, J. K(eds). *Proceedings of the XI International Symposium on Biological Control of Weeds,* Canberra, Australia, pp. 180-185.

394 Sousa, W. T. Z. (2011). *Hydrilla verticillata* (Hydrocharitaceae), a recent invader threatening Brazil’s freshwater environments: a review of the extent of the problem. *Hydrobiologia*, *669*(1), 1.

395 Spaulding, D. D. (2013). Key to the bindweeds (*Calystegia* and *Convolvulus*, Convolvulaceae) of Alabama and adjacent States. *Phytoneuron*, *83*, 1-12.

396 Spears Jr, E. E. (1987). Island and mainland pollination ecology of *Centrosema virginianum* and *Opuntia stricta*. *The Journal of Ecology*, 351-362.

397 Spencer, N. R., & Coulson, J. R. (1976). The biological control of alligatorweed, Alternanthera philoxeroides, in the United States of America. *Aquatic Botany, 2*, 177-190.

398 Stahevitch, A. E., Crompton, C. W., & Wojtas, W. A. (1988). The biology of Canadian weeds.: 85. *Euphorbia cyparissias* L. *Canadian Journal of Plant Science*, *68*(1), 175-191.

399 Starr, F., Starr, K., Loope, L., & Maui, H. I. (2003). *Acacia podalyriifolia*. United States Geological Survey-Biological Resources Division. Haleakala Field Station, Maui, Hawai'i. http://www.starrenvironmental.com/publications/species_reports/pdf/acacia_podalyriifolia.pdf.

400 Starr, F., Starr, K., Loope, L., & Maui, H. I. (2003). *Caesalpinia decapetala*. United states geological survey- Biological resources division, Halekala field station, Maui, Hawaii. http://hear.its.hawaii.edu/Pier/pdf/pohreports/caesalpinia_decapetala.pdf

401 Steppe, C., Wilson, S. B., Deng, Z., Druffel, K., & Knox, G. W. (2019). Morphological and cytological comparisons of eight varieties of trailing lantana (*Lantana montevidensis*) grown in Florida. *HortScience*, *54*(12), 2134-2138.

402 Stergios, B. G. (1976). Achene production, dispersal, seed germination, and seedling establishment of *Hieracium aurantiacum* in an abandoned field community. *Canadian Journal of Botany*, *54*(11), 1189-1197.

403 Steward, K. K., & Van, T. K. (1987). Comparative studies of monoecious and dioecious hydrilla (*Hydrilla verticillata*) biotypes. *Weed Science*, *35*(2), 204-210.

404 Stoller, E. W., & Sweet, R. D. (1987). Biology and life cycle of purple and yellow nutsedges (*Cyperus rotundus* and *C. esculentus*). *Weed Technology, 1*(1), 66-73.

405 Stone, G. N., Raine, N. E., Prescott, M., & Willmer, P. G. (2003). Pollination ecology of acacias (Fabaceae, Mimosoideae). *Australian Systematic Botany*, *16*(1), 103-118.

406 Subba Reddi, S., Reddi, E. U. B., & Reddi, N. S. (1981). Breeding Structure and Pollination Ecology of T ribulus terrestris. *Proceedings of the Indian National Science Academy, Part B. Biological sciences.*

407 Sun, M., & Ritland, K. (1998). Mating system of yellow starthistle (*Centaurea solstitialis*), a successful colonizer in North America. *Heredity, 80*(2), 225.

408 Swamy, P. S., & Ramakrishnan, P. S. (1987). Weed potential of *Mikania micrantha* HBK, and its control in fallows after shifting agriculture (Jhum) in North-East India. *Agriculture, ecosystems & environment*, *18*(3), 195-204.

409 Tallent-Halsell, N. G., & Watt, M. S. (2009). The invasive *Buddleja davidii* (butterfly bush). *The Botanical Review, 75(3)*, 292.

410 Talyor, D. (2019). Eastern priclly ear (*Opuntia humifusa* (Raf.) Raf.). Plant of the week. U.S. Forest service. https://www.fs.fed.us/wildflowers/plant-of-the-week/opuntia_humifusa.shtml.

411 Taylor, D. B., & Dhileepan, K. (2012). Comparative growth and biomass allocation of two varieties of cat's claw creeper, *Dolichandra unguis-cati* (Bignoniaceae) in Australia. *Australian Journal of Botany*, *60*(7), 650-659.

412 Taylor, R. J., & Harrod, R. J. (1995). Reproduction and pollination biology of *Centaurea* and *Acroptilon* species, with emphasis on *C. diffusa*. Northt'cst Sciencc. Vol. 69. No. 2.

413 Thomas, J., Hofmeyer, D., & Benwell, A. S. (2006). Bitou Bush control (after fire) in Bundjalung National Park on the New South Wales North Coast. *Ecological Management & Restoration*, *7*(2), 79-92.

414 Thullen, R. J., & Keeley, P. E. (1979). Seed production and germination in *Cyperus esculentus* and *C. rotundus*. *Weed Science*, *27*(5), 502-505.

415 Tiley, G. E. (2010). Biological Flora of the British Isles: *Cirsium arvense* (L.) Scop. *Journal of Ecology*, *98*(4), 938-983.

416 Tscheulin, T., & Petanidou, T. (2013). The presence of the invasive plant *Solanum elaeagnifolium* deters honeybees and increases pollen limitation in the native co-flowering species *Glaucium flavum*. *Biological invasions*, *15*(2), 385-393.

417 Tucker, G. C. (1990). The genera of Arundinoideae (Gramineae) in the southeastern United States. *Journal of the Arnold Arboretum*, *71*(2), 145-177.

418 Tunison, T. (ed) (2012). Element stewardship abstract for *Rubus argutus*. *The Nature Conservancy*. https://www.invasive.org/gist/esadocs/documnts/rubuarg.pdf.

419 Turner, C. E., Center, T. D., Burrows, D. W., & Buckingham, G. R. (1997). Ecology and management of *Melaleuca quinquenervia*, an invader of wetlands in Florida, USA. *Wetlands Ecology and Management*, *5*(3), 165-178.

420 Tutin, T. G. (1953). *Sarothamnus scoparius* subsp. *maritimus* (Rouy) Ulbrich, in new combinations in the British flora. *Watsonia*, *2*, 297.

421 Tybirk, K. (1993). Pollination, breeding system and seed abortion in some African acacias. *Botanical Journal of the Linnean Society*, *112*(2), 107-137.

422 Upadhyaya, M. K., Tilsner, H. R., & Pitt, M. D. (1988). The Biology Of Canadian Weeds.: 87. *Cynoglossum officinale* L. *Canadian Journal of Plant Science*, *68*(3), 763-774.

423 Ushimaru, A., & Kikuzawa, K. (1999). Variation of breeding system, floral rewards, and reproductive success in clonal Calystegia species (Convolvulaceae). *American Journal of Botany*, *86*(3), 436-446.

424 Van de Venter, H. A., Hosten, L., Lubke, R. A., & Palmer, A. R. (1984). Morphology of *Opuntia aurantiaca* (jointed cactus) biotypes and its close relatives, *O. discolor* and *O. salmiana* (Cactaceae). *South African Journal of Botany*, *3*(5), 331-339.

425 van Klinken, R. D., Campbell, S. D., Heard, T. A., McKenzie, J., & March, N. (2009). The Biology of Australian Weeds: 54.'*Parkinsonia aculeata*'L. *Plant Protection Quarterly*, *24*(3), 100.

426 Van Leeuwen, B. H. (1981). The role of pollination in the population biology of the monocarpic species *Cirsium palustre* and *Cirsium vulgare*. *Oecologia*, *51*(1), 28-32.

427 Vargas, T. E., & García, E. D. (1999). Clonal propagation of *Opuntia elatior* (Miller) from areoles. In *Anales de Botánica Agrícola* (Vol. 6, pp. 67-71).

428 Vargas-Mendoza, M. C., & González-Espinosa, M. (1992). Habitat heterogeneity and seed dispersal of *Opuntia streptacantha* (Cactaceae) in nopaleras of Central Mexico. *The Southwestern Naturalist*, 379-385.

429 Vitalos, M., & Karrer, G. (2008). Distribution of *Ambrosia artemisiifolia* L.-is birdseed a relevant vector. *Journal of Plant Diseases and Protection*, *21*, 345-348.

430 Vivian-Smith, G., & Panetta, F. D. (2004). Seed bank ecology of the invasive vine, cats claw creeper (*Macfadyena unguis-cati* (L.) A. Gentry). In Sindel, B. M., & Johnson, S. B. (eds). 14th Australian Weed Management Conference: *Weed management: balancing people, planet, profit,* Wagga Wagga, New South Wales, pp. 531-534.

431 Vivian-Smith, G., Lawson, B. E., Turnbull, I., & Downey, P. O. (2007). The biology of Australian weeds. 46. *Anredera cordifolia* (Ten.) Steenis. *Plant Protection Quarterly*, *22*(1), 2.

432 Vrieling, K., Saumitou-Laprade, P., Cuguen, J., Van Dijk, H., De Jong, T. J., & Klinkhamer, P. G. L. (1999). Direct and indirect estimates of the selfing rate in small and large individuals of the bumblebee pollinated *Cynoglossum officinale* L (Boraginaceae). *Ecology Letters*, *2*(5), 331-337.

433 Vujnovic, K., & Wein, R. W. (1997). The biology of Canadian weeds. 106. *Linaria dalmatica* (L.) Mill. Canadian Journal of Plant Science, 77(3), 483-491.

434 Vujnovic, K., & Wein, R. W. (1997). The biology of Canadian weeds. 106. *Linaria dalmatica* (L.) Mill. *Canadian Journal of Plant Science*, *77*(3), 483-491.

435 Wagner, W. L., Herbst, D. R., & Sohmer, S. H. (1999). *Manual of the flowering plants of Hawai'i*. University of Hawai'i Press. http://www.hear.org/PIER/pdf/pohreports/melastoma_candidum.pdf

436 Wakjira, M. (2011). An invasive alien weed giant sensitive plant (*Mimosa diplotricha* Sauvalle) invading Southwestern Ethiopia. *African Journal of Agricultural Research*, *6*(1), 127-131.

437 Wald, E. J., Kronberg, S. L., Larson, G. E., & Johnson, W. C. (2005). Dispersal of leafy spurge (*Euphorbia esula* L.) seeds in the feces of wildlife. *The American midland naturalist*, *154*(2), 342-357.

438 Walden, D., Finlayson, C. M., Van Dam, R., & Storrs, M. (2002). Information for a risk assessment and management of *Mimosa pigra* in Tram Chim National Park, Viet Nam. *Research Institute,* 160.

439 Wall, D. A., & Morrison, I. N. (1990). Phenological development and biomass allocation in *Silene vulgaris* (Moench) Garcke. *Weed Research*, *30*(4), 279-288.

440 Walton, C. S. (2003). *Leucaena lecuocephala*. https://www.daf.qld.gov.au/__data/assets/pdf_file/0009/57294/IPA-Leucaena-PSA.pdf.

441 Wang, R., & Kok, L. T. (1986). Host specificity of *Megacerus discoidus* (Coleoptera: Bruchidae) and its impact on hedge bindweed, *Calystegia sepium*. *Environmental entomology*, *15*(4), 834-838.

442 Ward, D. B. (2009). Keys to the flora of Florida: 23, Opuntia (Cactaceae). *Phytologia*, *91*, 383-393.

443 Ward, S. M., Fleischmann, C. E., Turner, M. F., & Sing, S. E. (2009). Hybridization between invasive populations of Dalmatian toadflax (*Linaria dalmatica*) and yellow toadflax (*Linaria vulgaris*). *Invasive Plant Science and Management*, *2*(4), 369-378.

444 Watson, A. K. (1980). The biology of Canadian weeds.: 43. *Acroptilon (Centaurea) repens* (L.) DC. *Canadian Journal of Plant Science*, *60*(3), 993-1004.

445 Watson, A. K., & Renney, A. J. (1974). The biology of Canadian weeds 6. *Centaurea Diffusa* And *C. maculosa. Canadian Journal of Plant Science*, *54*(4), 687-701.

446 Weaver, S. E., & Lechowicz, M. J. (1983). The biology of Canadian weeds.: 56. *Xanthium strumarium* L. *Canadian Journal of Plant Science*, *63*(1), 211-225.

447 Weaver, S. E., & Riley, W. R. (1982). The biology of Canadian weeds.: 53. *Convolvulus arvensis* L. *Canadian Journal of Plant Science*, *62*(2), 461-472.

448 Webb, C. J., Sykes, W. R., & Garnock-Jones, P. J. (1988). Flora of New Zealand Volume IV. Naturalised pteridophytes, gymnosperms, dicotyledons. Christchurch, Botany Division, DSIR.

449 Weed of Australia (2016). *Parthenium hysterophorus* L. https://keyserver.lucidcentral.org/weeds/data/media/Html/parthenium_hysterophorus.htm.

450 Weeds of Australia (2016). *Opuntia monacantha* (Willd.) Haw. https://keyserver.lucidcentral.org/weeds/data/media/Html/opuntia_monacantha.htm.

451 Weeds of Australia (2016). *Paraserianthes lophantha* (Willd.) I.C. Nielsen subsp. *lophantha*. https://keyserver.lucidcentral.org/weeds/data/media/Html/paraserianthes_lophantha_subsp._lophantha.htm.

452 Weeds of Australia (2016). *Passiflora tarminiana* Coppens & V.E. Barney. https://keyserver.lucidcentral.org/weeds/data/media/Html/passiflora_tarminiana.htm.

453 Weeds of Australia (2016). *Pereskia aculeata* Mill. https://keyserver.lucidcentral.org/weeds/data/media/Html/pereskia_aculeata.htm.

454 Weeds of Australia (2016). *Rubus alceifolius* Poir. https://keyserver.lucidcentral.org/weeds/data/media/Html/rubus_alceifolius.htm.

455 Weeds of Australia (2016). *Rubus fruticosus* L. sp. agg. https://keyserver.lucidcentral.org/weeds/data/media/Html/rubus_fruticosus_sp__agg.htm.

456 Weeds of Australia (2016). *Sida acuta* Burm. f. https://keyserver.lucidcentral.org/weeds/data/media/Html/sida_acuta.htm.

457 Weeds of Australia (2016). *Sida rhombifolia* L. https://keyserver.lucidcentral.org/weeds/data/media/Html/sida_rhombifolia.htm.

458 Weeds of Australia (2016). *Solanum mauritianum* Scop. https://keyserver.lucidcentral.org/weeds/data/media/Html/solanum_mauritianum.htm.

459 Weeds of Australia (2016). *Solanum viarum* Dunal. https://keyserver.lucidcentral.org/weeds/data/media/Html/solanum_viarum.htm.

460 Weeds of Australia fact sheet index (2016). *Cryptostegia grandiflora* (Roxb.) R. Br. https://keyserver.lucidcentral.org/weeds/data/media/Html/cryptostegia_grandiflora.htm.

461 Weeds of Australia fact sheet index (2016). *Heliotropium amplexicaule* Vahl. https://keyserver.lucidcentral.org/weeds/data/media/Html/heliotropium_amplexicaule.htm.

462 Weeds of Australia fact sheet index (2016). *Hypericum androsaemum* L. https://keyserver.lucidcentral.org/weeds/data/media/Html/hypericum_androsaemum.htm.

463 Weeds of Australlia (2016). *Rumex crispus* L. https://keyserver.lucidcentral.org/weeds/data/media/Html/rumex_crispus.htm.

464 Weiss, J., Nerd, A., & Mizrahi, Y. (1994). Flowering and pollination requirements in *Cereus peruvianus* cultivated in Israel. *Israel Journal of Plant Sciences*, *42*(2), 149-158.

465 Weiss, P. W. (1980). Germination, reproduction and interference in the amphicarpic annual *Emex spinosa* (L.) Campd. *Oecologia*, *45*(2), 244-251.

466 Weiss, P. W. (1981). Spatial distribution and dynamics of populations of the introduced annual *Emex australis* in south-eastern Australia. *Journal of Applied Ecology*, 849-864.

467 Weiss, P. W., Adair, R. J., Edwards, P. B., Winkler, M. A., & Downey, P. O. (2008). *Chrysanthemoides monilifera* subsp. monilifera (L.) T. Norl. and subsp. rotundata (DC.) T. Norl. *Plant Protection Quarterly*, *23*(1), 3.

468 Wen-Kun, H., Jian-Ying, G., Fang-Hao, W., Bi-Da, G., & Bing-Yan, X. (2008). AFLP analyses on genetic diversity and structure of *Eupatorium adenophorum* populations in China. *Chinese Journal of Agricultural Biotechnology*, *5*(1), 33-41.

469 Wester, L. L., & Wood, H. B. (1977). Koster's curse (*Clidemia hirta*), a weed pest in Hawaiian forests. *Environmental Conservation*, *4*(1), 35-41.

470 Whibley DJE, Symon DE, 1992. Acacias of South Australia (2nd edn). Handbook of the flora and fauna of South Australia. Adelaide: South Australian Government Printer.

471 Whitesides, R. E. (1978). Field bindweed: a growth stage indexing system and its relation to control with glyphosate. M.S Thesis, Oregon State University.

472 Whitson TD, Burrill LC, Dewey SA, Cudney DW, Nelson BE, Lee RD, Parker R, 1996. Weeds of the west. Laramie, Wyoming, USA: Western Society of Weed Science in cooperation with Cooperative Extension Services, University of Wyoming, 630 pp. *In* Invasive Species Compendium, *Centaurea iberica* (Lberian starthistle). https://www.cabi.org/isc/datasheet/109132#51D13E34-B997-4D2E-BB77-4C23B9088081.

473 Wilen, C. A. 2006. Puncturevine. Integrated pest management for home gardeners and landscape profesionals. Pest note publication 74128. University of california

agriculture and natural resources, USA. http://ipm.ucanr.edu/PDF/PESTNOTES/pnpuncturevine.pdf.

474 Williams, P. A., Karl, B. J., Bannister, P., & Lee, W. G. (2000). Small mammals as potential seed dispersers in New Zealand. *Austral Ecology*, 25, 523–532.

475 Wills, G. D. (1987). Description of purple and yellow nutsedge (*Cyperus rotundus* and *C. esculentus*). *Weed Technology*, *1*(1), 2-9.

476 Wilson, J. R., Gairifo, C., Gibson, M. R., Arianoutsou, M., Bakar, B. B., Baret, S., ... & Kull, C. A. (2011). Risk assessment, eradication, and biological control: global efforts to limit Australian acacia invasions. *Diversity and distributions*, *17*(5), 1030-1046.

477 Wilson, L. M., & Randall, C. B. (2005) (3rd edn,). Biology and biological control of knapweed. US Forest Service, Forest Health Technology Entreprise Team.

478 Wilson, L. M., Jette, C., Connett, J., & McAffrey, J. (2003). Biology and biological control of yellow starthistle. US Forest Service, Forest Health Technology Entreprise Team.

479 Wilson, P. J & Smith, A. (2008). *Centaurea cynas* L. *In* Online Atlas of the Birsith and Irish Flora. https://www.brc.ac.uk/plantatlas/plant/centaurea-cyanus.

480 Winston, R., Hansen, R., Schwarzlander, M., Coombs, E., Randall, C. B., & Lym, R. (2008). Biology and biological control of exotic true thistles. US Forest Service, Forest Health Technology Entreprise Team.

481 Witkowski, E. T. F., & Wilson, M. (2001). Changes in density, biomass, seed production and soil seed banks of the non-native invasive plant, *Chromolaena odorata*, along a 15 year chronosequence. *Plant Ecology*, *152*(1), 13-27.

482 Woodall, S. L. (1982). Seed dispersal in *Melaleuca quinquenervia*. *Florida Scientist*, 81-93.

483 Wright, M. A., Welsh, M., & Costea, M. (2011). Diversity and evolution of the gynoecium in Cuscuta (dodders, Convolvulaceae) in relation to their reproductive biology: two styles are better than one. *Plant Systematics and Evolution*, *296*(1-2), 51-76.

484 Zachariades, C., Day, M., Muniappan, R., & Reddy, G. V. P. (2009). *Chromolaena odorata* (L.) king and robinson (Asteraceae). In Raman, A., Reddy, G. P. V., & Muniapan, R. (eds). Biological control of tropical weeds using arthropods. Cambridge University Press, Cambridge, pp. 130-162.

485 Zappettini, G. (1953). The taxonomy of *Halogeton glomeratus*. *The American Midland Naturalist*, *50*(1), 238-247.

486 Zhang, L. Y., Ye, W. H., Cao, H. L., & Feng, H. L. (2004). *Mikania micrantha* HBK in China–an overview. *Weed Research*, *44*(1), 42-49.

487 Zimmermann, H. G. (1981). The ecology and control of *Opuntia aurantiaca* in South Africa in relation to the cochineal insect, *Dactylopius austrinus.* Dissertation, Rhodes University.

CHAPTER 3: SPECIALIZED SOIL TYPES AFFECT HOST ACCEPTABILITY AND PERFORMANCE OF WEED BIOCONTROL CANDIDATES: IMPLICATIONS FOR HOST SPECIFICITY ASSESSMENTS

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Abstract

The Eurasian gall-forming weevil *Ceutorhynchus cardariae* Korotyeav (Coleoptera: Curculionidae) is a biological control candidate for the invasive Eurasian *Lepidium draba* L. (Brassicaceae) in the western USA. Among 157 nontarget plant species that have been tested, some North American *Caulanthus* and *Streptanthus* species, confamilial with *Lepidium,* were found to be at potential risk of attack by *C*. *cardariae*. Many *Caulanthus* and *Streptanthus* species grow on serpentine soils, which are characterized by low nutrient content and high concentrations of various combinations of heavy metals. Some of these species accumulate heavy metals, which have been shown to act as deterrents against insect herbivory. Standard pre-release host specificity tests with *C. cardariae* used plants propagated on horticultural soils, which could have inflated performance by *C. cardariae* on *Caulanthus* and *Streptanthus* species. To examine this possibility, we assessed the performance of *C. cardariae* on three *Caulanthus* species, the federally listed threatened and endangered *Streptanthus glandulosus* ssp. *albidus,* and *Lepidium draba*, on plants propagated in horticultural soil or in native serpentine soil. Our study showed that native serpentine soil influenced *C*. *cardariae* attack. All plant species, including *L*. *draba,* received less feeding damage and gall formation when grown in serpentine soil. In addition, feeding by *C. cardariae* was much less and fewer galls were formed on the confamilial species than on *L. draba,* regardless of soil type. Our data show that native confamilial species restricted to specialized soil types may be at less risk of herbivore attack than predicted based on tests conducted in horticultural soil.

Keywords: Biocontrol, serpentine soil, host specificity, *Lepidium draba*, *Ceutorhynchus cardariae*

Introduction

Classical biological control of weeds requires extensive pre-release host specificity testing to ensure that biological control candidates are unlikely to harm nontarget plant species post-release (Hinz et al. 2019). Reliable pre-release assessment of biological control candidates remains a fundamental task in weed biological control (Schaffner et al. 2018). Typically, candidate species are exposed to nontarget plant species grown in nutrient-rich homogenous potting soils, but this could influence the susceptibility of nontarget species to herbivory that are adapted to special soil types (Meindl et al. 2013; Weyl et al. 2019b). For example, plant species adapted to nutrient-poor serpentine soils experienced lower herbivory when grown on these soils than when grown on more fertile soils (Meindl et al. 2013). If biocontrol candidates perform better on nontarget species grown in standardized soil than they do on the same species grown in their native soils, this could overestimate the likelihood of impacts on these nontarget species.

Soil physical and chemical properties vary across the landscapes and this variation can mediate insect-plant interactions through changes in plant tissue chemistry and morphology (Meindl et al. 2013). For example, plant species occurring on metal-rich (metalliferous) soils can have altered plant tissue chemistry or morphology, which in turn affect their interactions with herbivores (Boyd and Moar 1999; Meindl et al. 2013). Plant species adapted to metalliferous soil can accumulate several times higher concentrations of heavy metals (e.g., Ni, Co, Cr) than is normal for most plants (Reeves and Baker 2000; van der Ent et al. 2013), which may function as defense against herbivores (Boyd and Moar 1999; Martens and Boyd 1994) and pathogens (Boyd and Martens 1994). Plant species with elevated heavy metal concentrations defend against herbivores through two main mechanisms. Firstly, metal toxicity can cause lethal effects or sublethal effects such as reduced fecundity and/or decreased herbivore growth (Boyd and Martens 1994; Boyd and Moar 1999). Secondly, deterrence, in which herbivores avoid or consume less plant tissue from plants with elevated metal concentrations (Behmer et al. 2005; Kazemi-Dinan et al. 2015). Therefore, conducting host specificity tests with test plant species grown in their native soil, for example, metalliferous soil, could improve nontarget attack predictions. We hypothesized that attack by a candidate biocontrol agent is reduced on both target and nontarget species grown in metalliferous soil compared to plants grown in standard horticultural soil. Further, we hypothesized that relative attack among target and nontarget species grown in native metalliferous soils differs from relative attack when they are tested in horticultural soils. We tested these hypotheses in our system: the invasive weed, *Lepidium draba* L. (Brassicaceae), several nontarget species related to this weed, and a biological control candidate, the stem and petiole gall-forming weevil *Ceutorhynchus cardariae* Korotyeav (Coleoptera: Curculionidae).

Lepidium draba is a perennial clonal herb of Eurasian origin (Francis and Warwick 2008). Since its introduction to the USA in the late 19th century (Francis and Warwick 2008), *L. draba* has been spreading throughout the country and it is a declared noxious weed in 15 US states, particularly in the western USA (Gaskin et al. 2005a; USDA-NRCS 2021b). Field and laboratory studies suggest that *C. cardariae* is host specific to *L. draba* and that it has the potential to kill shoots prematurely and reduce the vigor of *L. draba* (Hinz and Diaconu 2015). Under no-choice testing conditions, host specificity tests conducted with 157 nontarget plant species predicted limited potential risk of spillover nontarget attack on confamilial native North American plant species in the genera *Caulanthus* and *Streptanthus* (*C. cardariae* petition, unpublished data, M. Schwarzländer et al.). As is typical, all these tests were conducted with plants grown in horticultural soil. However, many *Caulanthus* and *Streptanthus* species occur in or are endemic to serpentine soils, thus the risk that *C. cardariae* could attack these species under natural conditions may have been inaccurately assessed.

Over 90% of known metal hyperaccumulator plant species (species that can accumulate unusually high concentrations of metal in van der Ent et al. 2013) grow in serpentine soils (Pollard et al. 2014). Serpentine soils are formed by weathering of ultramafic rocks (an igneous rock with very low silica and rich in magnesium and iron containing minerals; Downes 2021), and are uncommon but occur in patches throughout North America (Whittaker 1954). The soils create a stressful environment for most plant species due to low concentrations of mineral nutrients (e. g. Ca, N, or P etc.), low Ca: Mg ratios and high concentrations of some heavy metals including Ni, Cr and Cd (Whittaker 1954). However, these soils host high levels of plant endemism where they occur (Anacker 2011). For example, California's serpentine soils harbor approximately 13% of the state's endemic flora. *Streptanthus* (Brassicaceae) is the most diverse genus within this flora with 18 serpentine endemic species, more than 7% of the serpentine-endemic species in California (Safford et al. 2005). *Caulanthus* species are also commonly reported occurring in serpentine soil in North America with at least one serpentine-endemic species in California (Al-Shehbaz 2012; Baldwin et al. 2012).

In a previous study, several species within *Caulanthus* and *Streptanthus* grown in horticultural soil were attacked by *C. cardariae* (Weyl et al. 2019b). Here, we compare attack by the same weevil on some of these species growing in native serpentine soil compared to horticultural soil to determine if nontarget risk assessments can be improved using plants grown in native soils.

Materials and Methods

Insect, plants and soil

Ceutorhynchus cardariae, which were originally collected at a field site in Romania (Hinz and Diaconu 2015), were reared at the CABI Switzerland Centre in Delémont, Switzerland and adults (n=300 and n=228) were sent to the University of Idaho Quarantine Facility, Moscow, Idaho, USA on November 21, 2017 and January 8, 2019, respectively. Weevils of the same sex were separated into groups of ten and placed in transparent plastic cylinders (11 cm diameter, 15 cm height, Semadeni AG, Ostermundigen, Switzerland), covered with a mesh lid. Excised *L. draba* leaves, on moist foam blocks (FloraCraft®, Ludington, Michigan, USA) in vacuum-sealed plastic (FoodSaver®, Atlanta, Georgia, USA) were provided as food to weevils in each container and leaves were changed every 2-3 days. *Ceutorhynchus cardariae* adults received on 21 November 2017 were kept inside an environmental chamber (Percival Scientific Incubator, Model C-30, Percival Scientific, Inc., Perry, Iowa, USA) at 12: 12 (L:D) at 5 °C to meet the overwintering requirements of the weevils until January 2018. All *C. cardariae* adults, including overwintered weevils received in 2019, were kept under ambient conditions from January 2019 in the quarantine laboratory with an average temperature 20.2 ± 0.5 °C and relative humidity 31.2 ± 1.3 % until experimentation.

Four annual herbaceous native North American plant species were selected for our study based on results of previous host specificity tests (*C. cardariae* petition, unpublished data, M. Schwarzländer et al.): A serpentine endemic and federally listed threatened and endangered species *Streptanthus glandulosus* subsp. *albidus* (Greene) Al-Shehbaz, M. S. Mayer & D.W. Taylor (Safford et al. 2005), *Caulanthus flavescens* (Hook.) E. B. Payson (=*Streptanthus flavescens* Hook) often occurring on serpentine soil (Baldwin et al. 2012), *Caulanthus anceps* E. B. Payson (=*Streptanthus anceps* (Payson) Hoover) rarely occurring on serpentine soil (Al-Shehbaz 2012) and *Caulanthus inflatus* (=*Streptanthus inflatus* (S. Watson) Greene) not recorded on serpentine soil. Seeds of *C. anceps*, *C. flavescens* and *C. inflatus* were obtained from the Rancho Santa Ana Botanical Garden, Claremont, California, USA and seeds of *S. glandulosus* ssp. *albidus* were provided by CABI Switzerland, which had previously obtained these as part of a previous study.

Serpentine soil was collected in Siskiyou County, California, USA (41.302630°N, 122.755312° W) from a site that could be accessed and for which no additional permits were required (Jodi Aceves, personal communication). Soil was collected on 28 March 2018 and immediately transported to the University of Idaho in sealed 19 l food-grade plastic buckets (20 buckets; API Kirk Containers, Commerce, California, USA). The soil was air dried in the laboratory and stored in the same plastic buckets until experimentation. Standardized horticultural soil (potting soil hereafter) was prepared by mixing 18 kg of Sunshine Professional Growing Mix #4 (SunGro® Horticulture Canada Ltd., Vancouver, Canada) with 2.5g trace elements (FRIT Industries, Inc., Ozark, Alabama, USA), 1.25g chelated iron (Grow More Inc., Gardena, California, USA), 48g triple super phosphate (Bonide Products, Inc., Oriskany, New York, USA), 185g Osmocote fertilizer (The Scotts Company LLC., Marysville, Ohio, USA) and 125g Dolomite lime (Grow More Inc., Gardena, California, USA).

Plants were propagated either through root cuttings (*L. draba*) or seeds (all other species) between 2 and 17 February 2019. *Lepidium draba* was propagated from one local clade (Clade-G) (Puliafico 2008) maintained at the University of Idaho *L. draba* genotype garden since 2007. The root cuttings were directly planted into black plastic pots (13 cm diameter, 13 cm height, McConkey, Sumner, Washington, USA) using potting soil or serpentine soil. Seeds of test species were soaked in tap water for an hour and the seed coat was carefully removed using forceps under a stereo microscope. Peeled seeds were germinated on filter paper moistened with distilled water in Petri dishes (11 cm diameter) for 48 hours. Seedlings were then transferred to seedling trays. After one week in the seedling tray, bare root seedlings were carefully transplanted into the same black plastic pots as *L. draba* above, filled with either potting soil or serpentine soil. All plants were maintained in an environmentally controlled greenhouse at ambient temperatures (14.2-21.1 ºC) and 16:8 (L:D) at the University of Idaho's Parker Research Farm, Moscow, Idaho, USA. All species were propagated successfully, except for *S. glandulosus* subsp. *albidus*, of which only three individuals could be grown.

<u>*Experimental setup*</u>

Ceutorhynchus cardariae males and females were kept together in plastic cylinders in a 2F:1M ratio two weeks prior to the setup of the experiment in order to facilitate mating. *Lepidium draba* leaves provided as food were dissected on a regular basis to monitor oviposition by females in all cylinders. A total of 163 potted plants were transferred to the University of Idaho quarantine facility to conduct no-choice feeding and development tests: 20 replicates of potting soil and serpentine soil for each of the three *Caulanthus* species and *L. draba*, and the three replicates of *S. glandulosus* subsp. *albidus* grown in serpentine soil. Each potted plant was individually caged with organdy (30 cm diameter, 60 cm height, Seattle Fabrics, Inc., Seattle, Washington, USA). Plants were arranged in randomized blocks (n=4) using four metal racks (12 cm by 45 cm by 183 cm) with 2 shelves each (for a total 8 shelves) (Trinity International Industries, Dallas, Texas, USA). Each shelf (approximately 80 cm height) was supplied with two full spectrum compound LED lights (Roleadro 300W LED Grow Light, Grow-light.org, San Francisco, California, USA) set to 14:10 (L: D). Racks were arranged next to each other in the quarantine facility.

Experiments were conducted between 10 March and 16 July 2019 at ambient temperatures (20.2 ± 0.5 °C). Experiments were conducted in four temporal cohorts (10, 13, 15 and 18 March 2019) and these cohorts represented the four blocks. Each cohort included 5 replicates of potting and serpentine soil grown plants of three test species and *L. draba* and one replicate of *S. glandulosus* subsp. *albidus* grown in serpentine soil for the first three cohorts (41 plants total).

No-choice developmental tests were conducted using methods similar to those described in Weyl et al. (2019b). Two mated females and one male of *C. cardariae* were placed onto individually caged test and *L. draba* plants. *Ceutorhynchus cardariae* adults were allowed to feed and oviposit on plants for 72 hours. They were then retrieved and placed back in plastic cylinders with cut *L. draba* foliage for two to three days to ensure females were still laying eggs before they were placed randomly on experimental plants of the next cohort. Following weevil retrieval, organdy cages were removed from experimental plants. Cages were replaced eight weeks later to capture emerging weevils after pupation. Experimental plants were checked for gall development two weeks following retrieval of weevils and adult emergence was recorded between eight and 18 weeks after parental weevils were retrieved. All newly emerged adults were immediately removed from plants. Since adult emergence was much less than expected from the number of galls on experimental plants, all plants with galls were dissected 18 weeks after the experimental setup. During dissection, both dead and living larvae were removed from the galls and counted. Larvae that were alive during dissection were treated as successful development for all subsequent analysis. At the end of the experiment, all aboveground plant biomass was harvested and dried in an oven (Model 637, Fisher Scientific, Waltham, Massachusetts, USA) at 65º C for 48 hours and weighted.

The growth of nontarget and *L. draba* plants was assessed by counting the total number of leaves and the length of the longest leaf (cm) of each plant at the experiment setup (10, 13, 15 and 18 March 2019), when plants were approximately one month old. *Ceutorhynchus cardariae* feeding was assessed by counting the number of leaves of each plant with and without feeding marks and expressed as the proportion of leaves fed upon. We also estimated the total leaf area consumed for each plant by counting the typical feeding punctures left by the weevil. Both variables, proportion of leaves with feeding and leaf area consumed, were recorded on the day of weevil retrieval (14, 17, 19 and 22 March 2019). For area consumed, the diameters of ten random feeding punctures were averaged for each individual plant with feeding punctures. This value was then used as a standard size multiplier to calculate the area consumed (mm^2) based on total feeding punctures of that plant.

Soil and plant elemental analysis

Four serpentine soil samples, 4-6 cores per sample using Tube Auger (2.54 cm diameter, Oakfield Apparatus, Oakfield, Wisconsin, USA) were taken at the time of collection on 28 March 2018 and stored in airtight zip-lock bags and airdried at the University of Idaho for 72 hours. Air dried serpentine soil samples were sent to the Research Analytical Laboratory, University of Minnesota, St Paul, Minnesota, USA for analysis of nutrient and heavy metal concentrations. For potting soil, four homogenous samples were taken, air dried for 72 hours and analyzed for nutrient and heavy metal concentrations at the University of Idaho's Analytical Science Laboratory, Moscow, Idaho, USA following a similar standardized laboratory procedure (Warner et al. 2018). Soil (1 g dry weight) was digested in trace metal grade nitric acid and 30% hydrogen peroxide. The digestate was then refluxed with concentrated reagent grade hydrochloric acid. The solution was then analyzed for total elemental concentrations, using inductively coupled plasma optical emission spectrometer (ICP-OES). Analyses included total elemental concentrations for Ca, K, P, Mg, Al, Cd, Co, Cr, Cu, Fe, Mn, Mo, Ni, and Zn (Appendix F).

Four leaves were collected from four to six plants of each species (except *S. glandulosus* subsp. *albidus*, due to the small plant numbers) from each soil type, one day prior to the start of the experiment. Plants were approximately one month old and plant leaves were sampled randomly within the plants. Leaves were pooled by plant species for each soil type due to the limited amount of foliage produced on plants grown in serpentine soil. Leaves were cleaned to remove surface soil contamination and oven-dried at 65° C for 48 hours. Leaves were analyzed at the University of Idaho's Analytical Soil Laboratory for elemental concentrations following standardized laboratory procedures (Anderson et al. 2010). Plant leaves were digested with concentrated trace metal grade nitric acid. After appropriate digestion and dilution, the solution was analyzed either with the Inductively Coupled Plasma Optical Emission Spectrometer (ICP-OES), or Inductively Coupled Plasma

Mass Spectrometer (ICP-MS). The analysis included Ca, P, K, Mg, S, Al, Cd, Cr, Co, Cu, Fe, Mn, Mo, Ni, and Zn (Appendix G).

Statistical analysis

A generalized linear mixed model was used to fit the randomized complete block design with experiment setup date as a random blocking effect and soil type, plant species and their interaction as fixed treatment effects. A zero-inflated negative binomial distribution model was used to analyze the number of galls developed. The proportion of leaves with feeding assumed a binomial distribution, while total leaves and number of galls assumed a negative binomial distribution. Leaf area consumed and aboveground dry weight assumed a normal distribution, while leaf length assumed a lognormal distribution (Stroup 2015). Logit link function was used for proportion of leaves with feeding, log link for total leaves and number of galls and identity link function for leaf length, aboveground dry biomass and leaf area consumed. Means comparisons were carried out with single degree-of-freedom contrasts. *Streptanthus glandulosus* subsp. *albidus* was not included in the analysis as only three plants grown on serpentine soil were available to weevils. Concentrations of soil elements were analyzed with generalized linear mixed model procedures with soil types as fixed effect, samples as random effects and assumed a normal distribution and used identity link function All analyses were conducted using SAS version 9.4 (SAS Institute 2015).

Results

Elemental analysis

Essential nutrients (P, K and Ca) concentrations were 15- to 25-fold higher for potting soil in comparison to serpentine soil (Appendix F). Serpentine soil contained higher concentrations of magnesium and some other metals (Co, Cr, Cu, Fe, Mn and Ni) (Appendix F), with greatest differences for Ni and Cr (380 and 111-fold, respectively), while the concentration of Zn was approximately double in potting soil (Appendix F). The Ca:Mg ratio was 400-fold higher in potting soil than that on serpentine soil (Appendix F). In addition, plant tissue elemental analysis showed that all plant species grown in serpentine soil had elevated metal concentrations in their tissue, particularly Cr, Ni and Fe compared to average tissue element concentrations of most plants (Appendix G).

Plant growth

After approximately one month of growth on both potting and serpentine soil, both soil type and plant species affected the number of leaves produced (Table 3.1; Fig. 3.1a). Across species, plants grown on serpentine soil produced 30.6 ± 5.4% (mean ± SE) fewer leaves compared to species grown in potting soil. There was no significant interaction between soil type and plant species for the number of leaves per plant (Table 3.1; Fig. 3.1a).

Length of leaves was also influenced by soil type and plant species (Table 3.1; Fig. 3.1b). The maximum length of leaves of plants grown in serpentine soil was 66.6 ± 5.9% (mean ± SE) shorter than the leaf length of plants grown in potting soil. There was a significant soil type by plant species interaction, indicating that soil type affected the leaf length differently in plant species. The leaf length reduction of plants grown in serpentine soil was greater for *C. anceps* than *C. flavescens* and *L. draba* and least in *C. inflatus* (Table 3.1; Fig. 3.1b).

Aboveground dry biomass of plant species measured at the end of the experiment differed between soil types and with plant species (Table 3.1; Fig. 3.1c). Aboveground biomass of plants grown in serpentine soil was 93.9 ± 1.6% (mean ± SE) less than those grown in potting soil. There was a significant soil type by plant species interaction reflecting a greater biomass reduction for *C. anceps* than *C. flavescens*, *C. inflatus* or *L. draba* (Table 3.1; Fig. 3.1c).

Ceutorhynchus cardariae herbivory

Over the 72-hour feeding period, the proportion of leaves with feeding marks from *C. cardariae* differed between soil type and among plant species (Table 3.2; Fig. 3.2a). The proportion of leaves with feeding marks across plant species was 21.9 ± 6.1% (mean ± SE) higher for plants grown in serpentine soil than those grown in potting soil. There was no interaction between soil type and plant species, indicating that feeding on all plant species was similarly affected by the soil type (Table 3.2; Fig. 3.2a).

The leaf area consumed by *C. cardariae* differed between soil types but not among plant species (Table 3.2; Fig. 3.2b). The weevils consumed 21.4 ± 3.9% (mean ± SE) less leaf area of plants grown in serpentine soil than of those plants grown in potting soil. There was no soil type by plant species interaction (Table 3.2; Fig. 3.2b).

In previous no-choice host range tests, *C. cardariae* produced galls on all plant species tested and larvae were able to successfully develop through to adults (Appendix E). The number of galls produced per plant was influenced by soil type and plant species (Table 3.3; Fig. 3.3). Plants grown in serpentine soil produced 82.5 ± 3.6% (mean ± SE) fewer galls per plant than plants grown in potting soil. Although the soil type by plant species interaction was not significant (Table 3.3; Fig. 3.3) the relative reduction in number of galls on serpentine soils was greater for *L. draba* and possibly for *C. anceps* than the other two species (Table 3.3; Fig. 3.3). One of the three *S. glandulosus* subsp. *albidus* plants grown in serpentine soil supported the development of a single *C. cardariae* gall without any adult emergence (Appendix H) but as stated above plants of this species were excluded from analyses.

Few adult *C. cardariae* emerged from galls in our experiment (total n=13 weevils) (Appendix H). Weevils emerged from galls produced on *L. draba* (84% of all weevils, n=11), *C. anceps* (7%, n=1) and *C. flavescens* (7%, n=1; Appendix H) and exclusively emerged from galls of plants grown in potting soil (Appendix H).

Discussion

The severity of attack by the biological control candidate *C. cardariae* on selected confamilial nontarget plant species grown in field-collected serpentine soil was lower compared to attack in plants grown in nutrient-rich potting soil, confirming the first hypothesis motivating this study. Our study also showed that plant species affected the number of galls produced on the different soil type, as the number of galls produced decreased more severely for *L. draba* in serpentine soil relative to potting soil than it did for the nontarget species in serpentine soil, confirming our second hypothesis for this herbivory variable. These findings highlight the need to understand the key ecological filters affecting attack by a potential biological control agent on nontarget species. Including host range tests under appropriate soil types, so as not to incorrectly estimate the risk of attack under natural conditions, may be especially important for those nontarget plant species that are restricted to specialized soil types, such as serpentine soil.

Soil elemental analysis in the current study showed that the serpentine soil used contained lower amounts of some mineral nutrients (P, K, Ca), reduced Ca: Mg ratio and higher concentrations of heavy metals compared to potting soil (Appendix F), supporting the notion that serpentine soils are edaphically stressful environments for plants (Kruckeberg 1985). In the current study this resulted in consistently smaller plants of all species grown in serpentine soils compared to plants grown in nutrient-rich potting soil, similar to the results reported by O'Dell et al. (2006). The reduced size of plant grown in serpentine soil reflects nutrient deprivation, but could also be linked to the metabolic cost of higher concentration of magnesium and heavy metals in the serpentine soil (Brady et al. 2005; Maestri et al. 2010).

The elemental analysis confirmed what is indicated by plant growth, that the plants accumulated higher concentrations of heavy metals in the serpentine soil (Appendix G). This is consistent with other studies reporting higher heavy metal concentrations in serpentine soil leading to elevated levels of heavy metals in tissues of plant species, especially in the Brassicaceae (Jhee et al. 2005; Kazemi-Dinan et al. 2015). Plant species adapted to metal-rich or serpentine soil, may be defended against plant herbivory by the elevated concentrations of heavy metals in their tissues (Behmer et al. 2005; Boyd and Martens 1994). Plant species with elevated metal concentrations defend against herbivores either using metal concentrations alone (Boyd and Martens 1994) or through additive effect between different metals, or metals and organic acids (Jhee et al. 2006a). In the present study, *C. cardariae* attacked all plant species and preferred *L. draba* 2:1 over the other plant species tested with regards to the proportion of leaves attacked, regardless of soil type, but consistantly fed less on those growing in serpentine soil while attacking more leaves per plant on all of them. This pattern suggests the plants in serpentine soil were less palatable or less preferred for feeding. Herbivores have been shown to preferrentially feed on low-metal concentration plants when compared to high-metal concentration plants (Behmer et al. 2005).

The number of galls on all plant species grown in serpentine soil was lower than on potting soil, with *C. cardariae* clearly prefering *L. draba* over nontargets in potting soil but that preference was less distinct when plants were grown in serpentine soil, however a smilar pattern is evident. Gall initiation is a function of *C. cardariae* oviposition or attempted oviposition (i.e. a gall may form without egg deposition) (Hinz and Diaconu 2015) and consequently, the lower gall numbers on serpentine soil-grown plants may indicate avoidance behavior by *C. cardariae* females. Mogren and Trumble (2010) reported that female insectss may avoid toxic substrates for ovipositon to protect their progeny from possible exposure to toxic metal-rich plant tissue. Diamondback moth females, *Plutella xylostella* L. (Lepidoptera: Plutellidae), laid more eggs on low-Ni compared to high-Ni concentration leaves of *Streptanthus polygaloides* Gray (Brassicaceae) (Jhee et al. 2006b), and female *Drosophila melanogaster* Meigen (Diptera: Drosophilidae) avoided high-metal concentrations substrate for oviposition (Bahadorani and Hilliker 2009).

Nontarget plant species grown in native metal-rich soil can cause delayed development and increased mortality of immature stages of insects, with toxicity increasing with exposure duration (Trumble and Jensen 2004). *Ceutorhynchus cardariae* development, from eggs to adult takes about 12 weeks in its native range (Hinz and Diaconu 2015). In our study, first adults emerged from *L. draba* grown in potting soil after about 10 weeks, while there was no adult development recorded from nontarget plant species grown in serpetine soil after 18 weeks, including *L. draba* grown in serpentine soil. This is longer that previously reported for *C. cardariae* (Hinz and Diaconu 2015) in which plant species supported weevil development in host specificity tests, with a mean of 11 adults per plant for L. *draba* and between 0.1- 4.6 adults per plant for test plant species in question (Apendix E). A plausible explaination is that the elevated metal levels in the gall tissues due to serpentine soils affected *C. cardariae* development and caused high larval mortality. An herbivore not typically associated with host plants growing in serpentine soils such as *C. cardariae* may be especially vulnerable to heavy metal defensive function compared to herbivores co-evolved with serpentine endemics. For example, the development of *Chrysolina pardalina* (Fabricius) (Coleoptera: Chrysomilidae) is unhindered on the serpentine-endemic *Berkheya coddll* Roessl. (Asteraceae), and similarly *Melanotrichus boydi* Schwartz and Wall (Hemiptera: Miridae) on *Streptanthus polygaloides*, because they are adapted to tolerate higher concentrations of heavy metals (Przybylowicz and Mesjasz-Przybylowicz 2001; Wall and Boyd 2006).

In summary, *C. cardariae* prefers its host *L. draba* for feeding and oviposition over all nontarget plant species tested, regardless of soil type. Fewer galls developed on test species than on *L. draba*, whether grown in potting soil or in serpentine soil. In addition, all plant species growin in serpentine soil supported fewer galls compared to plants grown in potting soil. Additionally, it appears that the three *Caulanthus* species used in our study can accumulate elevated concentrations of heavy metals when grown in serpentine soil (Appendix G) without autotoxicity symptoms such as leaf chlorosis and necrosis (S. Panta personal observation). Therefore, we can expect lower risk of attack from *C. cardariae* on *Caulanthus* species or populations that occur on serpentine soils.

Host specificity tests conducted previously cannot rule out the possibility of nontarget attack but these tests were all conducted on plants grown in nutritionally balanced potting soil. The current study suggests that native soil types such as serpentine soil, influence *C. cardariae* attack calling prior results into question. All plant species, including *L. draba* grown in serpentine soil received less leaf damage and supported fewer galls compared to plants grown in standardized potting soil. We suggest that host range tests conducted using potting soil may need to be carefully interpreted since severity and risk of nontarget attack by biocontrol agents may be mediated by soil types to which nontarget plant species are adapted or restricted. We contend that soil type can act as an ecological filter, in addition to other biotic and abiotic factors, in further restricting the ecological host range of *C. cardariae*, especially for about one third of *Streptanthus* species (total 35 species) and one fifth of *Caulanthus* species (total 17 species) that are endemic to or tolerant of serpentine soil in North America.

References

Al-Shehbaz IA (2012) *Caulanthus anceps*. Jepson flora project. Jepson eflora. https://ucjeps.berkeley.edu/eflora/eflora_display.php?tid=18393. Accessed 15 February 2021

Anacker BL (2011) Phylogenetic patterns of endemism and diversity. In: Harrison S, Rajakaruna N (eds) Serpentine: the evolution and ecology of a model system. University of California Press, Berkeley, pp 49-70

Anderson K, Farwell G, Gibson P, Ricks B, Case T (2010) Total recoverable elements in biological, plant, and animal tissue and feed samples. Analytical sciences laboratory standard methods by regents of the University of Idaho SMM.57.070.02: 1-11

Ani O, Onu O, Okoro G, Uguru M (2018) Overview of biological methods of weed control. In: Radhakrishnan R (ed) Biological approaches for controlling weeds. IntechOpen, London, pp 5-16

Bahadorani S, Hilliker AJ (2009) Biological and behavioral effects of heavy metals in *Drosophila melanogaster* adults and larvae. J Insect Behav 22:399-411

Baldwin BG, Goldman DH, Keil DJ, Patterson R, Rosatti TJ, Vorobik LA (2012) The Jepson manual: vascular plants of California, 2nd edn. University of California Press, Berkeley

Behmer ST, Lloyd CM, Raubenheimer D, Stewart-Clark J, Knight J, Leighton RS, Harper FA, Smith JAC (2005) Metal hyperaccumulation in plants: mechanisms of defence against insect herbivores. Funct Ecol 19:55-66

Bellue MK (1946) Weed seed handbook. Series VI. Mon Bull Dept Agric State Calif 35:159

Blossey B, Hunt-Joshi TR (2003) Belowground herbivory by insects: influence on plants and aboveground herbivores. Annu Rev Entomol 48:521-547

Blossey B, Skinner LC, Taylor J (2001) Impact and management of purple loosestrife (*Lythrum salicaria*) in North America. Biodiversity & Conservation 10:1787-1807

Boyd RS, Martens SN (1994) Nickel hyperaccumulated by *Thlaspi montanum* var. *montanum* is acutely toxic to an insect herbivore. Oikos 70:21-25

Boyd RS, Moar WJ (1999) The defensive function of Ni in plants: response of the polyphagous herbivore *Spodoptera exigua* (Lepidoptera: Noctuidae) to hyperaccumulator and accumulator species of *Streptanthus* (Brassicaceae). Oecologia 118:218-224

Brady KU, Kruckeberg AR, Bradshaw Jr. HD (2005) Evolutionary ecology of plant adaptation to serpentine soils. Annu Rev Ecol Evol Syst 36:243-266

Briese D (2000a) Impact of the Onopordum capitulum weevil *Larinus latus* on seed production by its host-plant. J Appl Ecol 37:238-246

Briese D (2000b) Impact of the Onopordum capitulum weevil Larinus latus on seed production by its host-plant. J Appl Ecol 37:238-246

Brooks ML, D'antonio CM, Richardson DM, Grace JB, Keeley JE, DiTomaso JM, Hobbs RJ, Pellant M, Pyke D (2004) Effects of invasive alien plants on fire regimes. Bioscience 54:677-688

Burdon J, Marshall D (1981) Biological control and the reproductive mode of weeds. J Appl Ecol:649-658

CABI (2022) CABI Species Compendium. https://www.cabi.org/ISC/.

Caesar A (2003) Synergistic interaction of soilborne plant pathogens and root-attacking insects in classical biological control of an exotic rangeland weed. Biol Control 28:144-153

Callaway RM, Thelen GC, Rodriguez A, Holben WE (2004) Soil biota and exotic plant invasion. Nature 427:731-733

Canavan K, Paterson ID, Ivey P, Sutton GF, Hill MP (2021) Prioritisation of targets for weed biological control III: a tool to identify the next targets for biological control in South Africa and set priorities for resource allocation. Biocontrol Sci Technol 31:584-601

Chaboudez P, Sheppard AW Are particular weeds more amenable to biological control? A reanalysis of mode of reproduction and life history. In: Proceedings of the Eighth International Symposium on Biological Control, 1995. DSIR/CSIRO, pp 95-102

Cilliers CJ, Hill MP, Ogwang JA, Ajuonu O (2003) Aquatic weeds in Africa and their control. Biological control in IPM systems in Africa:161-178

Clewley GD, Eschen R, Shaw RH, Wright DJ (2012) The effectiveness of classical biological control of invasive plants. J Appl Ecol 49:1287-1295

Cornell HV, Hawkins BA (1995) Survival patterns and mortality sources of herbivorous insects: some demographic trends. The American Naturalist 145:563-593

Corns WG, Frankton C (1952) Hoary cresses in Canada with particular reference to their distribution and control in Alberta. Sci Agri 32:484-495

Crawley MJ (1989) Insect herbivores and plant population dynamics. Annu Rev Entomol 34:531-562

Cullen J, Sheppard A, Raghu S (2022) Effectiveness of classical weed biological control agents released in Australia. Biol Control 166:104835

Culliney TW (2005) Benefits of classical biological control for managing invasive plants. Crit Rev Plant Sci 24:131-150

Davis AS, Landis DA, Nuzzo V, Blossey B, Gerber E, Hinz HL (2006) Demographic models inform selection of biocontrol agents for garlic mustard (Alliaria petiolata). Ecol Appl 16:2399-2410

Day MD, Urban AJ (2004) Ecological basis for selecting biocontrol agents for lantana. In: Cullen JM, Briese DT, Kriticos DJ, Lonsdale WM, Morin L, Scott JK (eds) XI International Symposium on Biological Control of Weeds, Canberra, Australia, 27 Spril- 2 May 2003. CSIRO Entomology, Australia, p 81

Dhileepan K, Trevino M, Snow L (2006) Application to release the leaf-sucking bug Carvalhotingis visenda (Hemiptera: Tingidae), a potential biological control agent for cat's claw creeper Macfadyena unguis-cati (Bignoniaceae). Alan Fletcher Research Station, Queensland Department of Natural Resources, Mines and Water, Brisbane:26

DiTomaso JM, Brooks ML, Allen EB, Minnich R, Rice PM, Kyser GB (2006) Control of invasive weeds with prescribed burning. Weed Technol 20:535-548

Downes H (2021) Ultramafic rocks. In: Alderton D, Elias SA (eds) Encyclopedia of geology, 2nd edn. Academic Press, Oxford, pp 69-75

Downey PO, Paterson ID, Canavan K, Hill MP (2021) Prioritisation of targets for weed biological control I: a review of existing prioritisation schemes and development of a system for South Africa. Biocontrol Sci Technol 31:546-565

Dunn CE (2007) New perspectives on biogeochemical exploration. Paper 12. Advances in prospect-scale geochemical methods. In: Milkereit B (ed) Proceedings of Exploration 07: Fifth decennial international conference on mineral exploration, Toronto, Canada, Sep 9-12 2007. pp 249-261

Egli D, Olckers T (2017) Establishment and impact of insect agents deployed for the biological control of invasive Asteraceae: prospects for the control of Senecio madagascariensis. BioControl 62:681-692

Ehrenfeld JG (2010) Ecosystem consequences of biological invasions. Annu Rev Ecol, Evol Syst 41:59-80

Feeny P (1976) Plant Apparency and Chemical Defense. In: Wallace JW, Mansell RL (eds) Biochemical Interaction Between Plants and Insects. Springer US, Boston, MA, pp 1-40. doi:10.1007/978-1-4684-2646-5_1

Forno I, Julien M (2000) Success in biological control of aquatic weeds by arthropods. In: Biological control: measures of success. Springer, pp 159-187

Fowler SV, Syrett P, Hill RL (2000) Success and safety in the biological control of environmental weeds in New Zealand. Austral Ecol 25:553-562

Francis A, Warwick SI (2008) The biology of Canadian weeds. 3. *Lepidium draba* L., *L. chalepense* L., *L. appelianum* Al-Shehbaz (updated). Can J Plant Sci 88:379-401

Gaskin JF (2006) Clonal structure of invasive hoary cress (*Lepidium draba*) infestations. Weed Sci 54:428-434

Gaskin JF, Bon M-C, Cock MJ, Cristofaro M, De Biase A, De Clerck-Floate R, Ellison CA, Hinz HL, Hufbauer RA, Julien MH (2011) Applying molecular-based approaches to classical biological control of weeds. Biol Control 58:1-21

Gaskin JF, Zhang D, Bon M (2005a) Invasion of *Lepidium draba* (Brassicaceae) in the western United States: distributions and origins of chloroplast DNA haplotypes. Mol Ecol 14:2331-2341

Gaskin JF, ZHANG DY, BON MC (2005b) Invasion of Lepidium draba (Brassicaceae) in the western United States: distributions and origins of chloroplast DNA haplotypes. Mol Ecol 14:2331-2341

Goeden R (1983) Critique and revision of Harris' scoring system for selection of insect agents in biological control of weeds. Protection Ecology 5:287-301

Goeden R, Ricker D (1979) Field analyses of Coleophora parthenica (Lep.: Coleophoridae) as an imported natural enemy of Russian thistle, Salsola iberica, in the Coachella Valley of southern California. Environ Entomol 8:1099-1101

Graves-Medley M, Mangold J (eds) (2018) Biology, ecology and management of whitetop (*Lepidium* spp.)(Revised). University Extension Publication, Bozeman, MT

Groh H (1940) Turkestan alfalfa as a medium of weed introduction. Sci Agri 21:36-43

Harms NE, Cronin JT, Diaz R, Winston RL (2020) A review of the causes and consequences of geographical variability in weed biological control successes. Biol Control:104398

Harris P (1973) The selection of effective agents for the biological control of weeds. The Canadian Entomologist 105:1495-1503

Harris P (1991) Classical biocontrol of weeds: Its definitions, selection of effective agents, and administrative-political problems.

Heard TA (2002) Host specificity testing of biocontrol agents of weeds. In: Smith CW, Denslow JE, Hight SD (eds) Proceedings of a workshop on biological control of invasive plants in native hawaiian ecosystems. , Manoa, Hawaii, 2002. Pacific cooperative studies unit. University of Hawaii, pp 21-29

Hinz HL, Borowiec N, Coromoto CY, Cortat G, Cuenot M, Grecu M, Szucs M (2006) Biological control of whitetops, *Lepidium draba* and *L. appelianum.* Annual report, Unpublished. CABI, Switzerland, Delémont

Hinz HL, Diaconu A (2015) Biology and field host range of *Ceutorhynchus cardariae*, a potential biological control agent for *Lepidium draba*. J Appl Entomol 139:168-178

Hinz HL, Winston RL, Schwarzländer M (2019) How safe is weed biological control? A global review of direct nontarget attack. Q Rev Biol 94:1-27

Impson F, Kleinjan C, Hoffmann J (2021) Suppression of seed production as a long-term strategy in weed biological control: The combined impact of two biocontrol agents on Acacia mearnsii in South Africa. Biol Control 154:104503

Impson F, Moran V, Hoffmann J (2004) Biological control of an alien tree, Acacia cyclops, in South Africa: impact and dispersal of a seed-feeding weevil, Melanterius servulus. Biol Control 29:375-381

Impson FA, Hoffmann JH (2019) The efficacy of three seed-destroying Melanterius weevil species (Curculionidae) as biological control agents of invasive Australian Acacia trees (Fabaceae) in South Africa. Biol Control 132:1-7

Jeschke J, Pyšek P (2018) Tens rule. In: Jeschke JM, Heger T (eds) Invasion biology: hypotheses and evidence. CABI Invasive Series. CABI, UK, pp 124-132

Jhee EM, Boyd RS, Eubanks MD (2005) Nickel hyperaccumulation as an elemental defense of *Streptanthus polygaloides* (Brassicaceae): influence of herbivore feeding mode. New Phytol 168:331-344

Jhee EM, Boyd RS, Eubanks MD (2006a) Effectiveness of metal–metal and metal–organic compound combinations against *Plutella xylostella*: implications for plant elemental defense. J Chem Ecol 32:239-259

Jhee EM, Boyd RS, Eubanks MD, Davis MA (2006b) Nickel hyperaccumulation by *Streptanthus polygaloides* protects against the folivore *Plutella xylostella* (Lepidoptera: Plutellidae). Plant Ecol 183:91-104

Julien M (1989) Biological control of weeds worldwide: trends, rates of success and the future.

Julien MH (1982) Biological control of weeds—a world catalogue of agents and their target weeds, 1st edn. CABI International, Wallingford

Julien MH (1987) Biological control of weeds—a world catalogue of agents and their target weeds, 2nd edn. CABI International, Wallingford

Julien MH (1992) Biological control of weeds worldwide: trends, rates of success and the future, 3rd edn. Oxford University Press, Oxford

Julien MH, Griffiths MW (1998) Biological control of weeds: a world catalogue of agents and their target weeds, 4th edn. CABI International, Wallingford

Kazemi-Dinan A, Barwinski A, Stein RJ, Krämer U, Müller C (2015) Metal hyperaccumulation in Brassicaceae mediates defense against herbivores in the field and improves growth. Entomol Exp Appl 157:3-10

Kelton JA, Price AJ (2009) Weed science and management. In: Verheye WH (ed) Soils, plant growth and crop production, in encyclopedia of life support systems (EOLSS), developed under the auspices of the UNESCO. EOLSS Publishers, Oxford, pp 76-101

Kéry M, Matthies D, Fischer M (2001) The effect of plant population size on the interactions between the rare plant Gentiana cruciata and its specialized herbivore Maculinea rebeli. J Ecol 89:418-427

Kirk LE, Pavlychenko TK, Kossar W (1943) Report of the investigations at the Research Laboratory of Plant Ecology. University of Saskatchewan, Regina, Canada

Korotyaev BA (1992) New and little-known species of weevil (Coleoptera: Curculionidae) from Russia and the adjacent countries. Revue d'Entomologie 71:807-833

Kruckeberg AR (1985) California serpentines: flora, vegetation, geology, soils, and management problems. University of California Press, Berkeley

Kurtz B, Karlovsky P, Vidal S (2010) Interaction between western corn rootworm (Coleoptera: Chrysomelidae) larvae and root-infecting Fusarium verticillioides. Environ Entomol 39:1532-1538

Lau JA (2013) Trophic consequences of a biological invasion: do plant invasions increase predator abundance? Oikos 122:474-480

Li J, Ye W-H (2006) Genetic diversity of alligator weed ecotypes is not the reason for their different responses to biological control. Aquat Bot 85:155-158

Liao C, Peng R, Luo Y, Zhou X, Wu X, Fang C, Chen J, Li B (2008) Altered ecosystem carbon and nitrogen cycles by plant invasion: a meta-analysis. New Phytol 177:706-714

Mack RN (2011) Cheatgrass. In: Simberloff D, Rejmánek M (eds) Encyclopedia of biological invasions. vol 3. Univ of California Press, Berkeley, pp 108-113

Maestri E, Marmiroli M, Visioli G, Marmiroli N (2010) Metal tolerance and hyperaccumulation: costs and trade-offs between traits and environment. Environ Exp Bot 68:1-13

Marohasy J (1998) The design and interpretation of host-specificity tests for weed biological control with particular reference to insect behaviour. Biocontrol News Inf 19:13N-20N

Martens SN, Boyd RS (1994) The ecological significance of nickel hyperaccumulation: a plant chemical defense. Oecologia 98:379-384

Martini F, Aluthwattha ST, Mammides C, Armani M, Goodale UM (2021) Plant apparency drives leaf herbivory in seedling communities across four subtropical forests. Oecologia 195:575-587

Matarczyk JA, Willis AJ, Vranjic JA, Ash JE (2002) Herbicides, weeds and endangered species: management of bitou bush (*Chrysanthemoides monilifera* ssp. *rotundata*) with glyphosate and impacts on the endangered shrub, *Pimelea spicata*. Biol Conserv 108:133-141

McClay A (1989a) Selection of suitable target weeds for classical biological control in Alberta. Selection of suitable target weeds for classical biological control in Alberta. Alberta Environmental Centre, Alberta

McClay A (1989b) Selection of suitable target weeds for classical biological control in Alberta. Selection of suitable target weeds for classical biological control in Alberta

McEvoy PB, Coombs EM (1999) Biological control of plant invaders: regional patterns, field experiments, and structured population models. Ecol Appl 9:387-401

McFadyen REC (1998) Biological control of weeds. Annu Rev Entomol 43:369-393

McInnis ML, Kiemnec GL, Larson LL, Carr J, Sharratt D (2003) Heart-podded hoary cress. Rangelands 25:18-23

Mealor BA, Hild AL, Shaw NL (2004) Native plant community composition and genetic diversity associated with long-term weed invasions. West N Am Nat:503-513

Meindl GA, Bain DJ, Ashman TL (2013) Edaphic factors and plant–insect interactions: direct and indirect effects of serpentine soil on florivores and pollinators. Oecologia 173:1355-1366

Milbrath LR, Davis AS, Biazzo J (2018) Identifying critical life stage transitions for biological control of long-lived perennial *Vincetoxicum* species. J Appl Ecol 55:1465-1475

Mogren CL, Trumble JT (2010) The impacts of metals and metalloids on insect behavior. Entomol Exp Appl 135:1-17

Moran V, Zimmermann H (1984) The biological control of cactus weeds: achievements and prospects. Biocontrol News and Information (UK)

Mulligan GA, Findlay JN (1974) The biology of Canadian weeds. 3. *Cardaria draba*, *C. chalepensis*, and *C. pubescens*. Can J Plant Sci 54:149-160

Mulligan GA, Frankton C (1962) Taxonomy of the genus *Cardaria* with particular reference to the species introduced into North America. Can J Bot 40:1411-1425

O'Dell RE, James JJ, Richards JH (2006) Congeneric serpentine and nonserpentine shrubs differ more in leaf Ca: Mg than in tolerance of low N, low P, or heavy metals. Plant Soil 280:49-64

Paterson ID, Hill MP, Canavan K, Downey PO (2021) Prioritisation of targets for weed biological control II: the South African Biological Control Target Selection system. Biocontrol Sci Technol 31:566-583

Paynter Q, Fowler SV, Groenteman R (2018) Making weed biological control predictable, safer and more effective: perspectives from New Zealand. BioControl 63:427-436

Paynter Q, Overton JM, Hill RL, Bellgard SE, Dawson MI (2012) Plant traits predict the success of weed biocontrol. J Appl Ecol 49:1140-1148

Paynter Q, Peterson P, Cranwell S, Winks CJ, McGrath Z (2019) Impact of generalist predation on two weed biocontrol agents in New Zealand. New Zealand Plant Protection 72:260-264

Pierson FB, Williams CJ, Hardegree SP, Weltz MA, Stone JJ, Clark PE (2011) Fire, plant invasions, and erosion events on western rangelands. Rangeland Ecol Manage 64:439-449

Pimentel D (2009) Invasive plants: their role in species extinctions and economic losses to agriculture in the USA. In: Inderjit (ed) Management of invasive weeds. Invading Nature - Springer Series in Invasion Ecology. Springer, Dordrecht, pp 1-7

Pollard AJ, Reeves RD, Baker AJ (2014) Facultative hyperaccumulation of heavy metals and metalloids. Plant Sci 217:8-17

Przybylowicz WJ, Mesjasz-Przybylowicz J (2001) Phytophagous insects associated with the Ni-hyperaccumulating plant *Berkheya coddii* (Asteraceae) in Mpumalanga, South Africa. S Afr J Sci 97:596-598

Puliafico KP (2008) Influence of insect herbivory, plant competition and plant defense on the invasion success of hoary cress (*Lepidium draba* L.(Brassicaceae)). Dissertation, University of Idaho

Pyšek P, Hulme PE, Simberloff D, Bacher S, Blackburn TM, Carlton JT, Dawson W, Essl F, Foxcroft LC, Genovesi P (2020) Scientists' warning on invasive alien species. Biological Reviews 95:1511-1534

Pyšek P, Jarošík V, Hulme PE, Pergl J, Hejda M, Schaffner U, Vilà M (2012) A global assessment of invasive plant impacts on resident species, communities and ecosystems: the interaction of impact measures, invading species' traits and environment. Global Change Biol 18:1725-1737

Reeves RD, Baker AJ (2000) Metal-accumulating plants. In: Raskin I, Ensley BD (eds) Phytoremediation of toxic metals: using plants to clean up the environment. Wiley, New York, pp 193-229

Reeves RD, Brooks RR, Macfarlane RM (1981) Nickel uptake by Californian *Streptanthus* and *Caulanthus* with particular reference to the hyperaccumulator *S. polygaloides* Gray (Brassicaceae). Am J Bot 68:708-712

Root RB (1973) Organization of a plant-arthropod association in simple and diverse habitats: the fauna of collards (Brassica oleracea). Ecol Monogr 43:95-124

Roshon RD, McCann JH, Thompson DG, Stephenson GR (1999) Effects of seven forestry management herbicides on *Myriophyllum sibiricum*, as compared with other nontarget aquatic organisms. Canadian journal of forest research 29:1158-1169

Safford HD, Viers JH, Harrison SP (2005) Serpentine endemism in the California flora: a database of serpentine affinity. Madrono 52:222-257

SAS Institute (2015) Base SAS 9.4 Procedures Guide. SAS Institute, Cary, North Carolina, United States of America

Schaffner U, Smith L, Cristofaro M (2018) A review of open-field host range testing to evaluate non-target use by herbivorous biological control candidates. BioControl 63:405-416

Schwarzländer M, Hinz HL, Winston RL, Day MD (2018) Biological control of weeds: an analysis of introductions, rates of establishment and estimates of success, worldwide. BioControl 63:319-331

Schwarzländer M, Hinz HL, Winston RL, Weyl P (2019) A petition for the introduction and open-field release of the Gall-forming weevil *Ceutorhynchus cardariae* (Coleoptera: Curculionidae) for the biological control of hoary cress species (*Lepidium draba*, *Lepidium chalepense* and *Lepidium appelianum*) in North America.

Scurfield G (1962) *Cardaria Draba* (L.) Desv. J Ecol 50:489-499

Selleck GW (1965) An ecological study of lens-and globe-podded hoary cresses in Saskatchewan. Weeds 13:1-5

Sheppard A (2003) Prioritising agents based on predicted efficacy: beyond the lottery approach. Improving the selection, testing and evaluation of weed biological control agents 7:11-21

Sheppard AW (2006) How to best select an agent for weed biological control. In: Hoddle MS, Johnson MW (eds) The Californian Conference on Biological Control–V, Riverside, USA, 2006. University of California Citrus Research Center and Agricultural Experiment Station, pp 55-65

Sholes OD (2008) Effects of associational resistance and host density on woodland insect herbivores. J Anim Ecol:16-23

Simberloff D (2011) How common are invasion-induced ecosystem impacts? Biol Invasions 13:1255-1268

Simberloff D, Martin J-L, Genovesi P, Maris V, Wardle DA, Aronson J, Courchamp F, Galil B, García-Berthou E, Pascal M (2013) Impacts of biological invasions: what's what and the way forward. Trends Ecol Evol 28:58-66

Simelane DO (2010) Potential impact of an introduced root-feeding flea beetle, Longitarsus bethae, on the growth and reproduction of an invasive weed, Lantana camara. Biol Control 54:114-118

Stephens AE, Myers JH (2012) Resource concentration by insects and implications for plant populations. J Ecol 100:923-931

Straw N, Sheppard A (1995) The role of plant dispersion pattern in the success and failure of biological control. In: Delfosse ES, Scott RR (eds) Proceedings of the Eighth International Symposium on Biological Control of Weeds, Linclon University, Cantebury, New Zealand, 2-7 February 1992. DSIR/CSIRO, Melbourne, pp 161-168

Strawn DG, Bohn HL, O'Connor GA (2019) Soil chemistry. 5th edn. John Wiley & Sons Ltd., New Jersey

Stroup WW (2015) Rethinking the analysis of non-normal data in plant and soil science. Agron J 107:811-827

Thomas MB, Reid AM (2007) Are exotic natural enemies an effective way of controlling invasive plants? Trends Ecol Evol 22:447-453

Trumble JT, Jensen PD (2004) Ovipositional response, developmental effects and toxicity of hexavalent chromium to *Megaselia scalaris,* a terrestrial detritivore. Arch Environ Contam Toxicol 46:372-376

USDA-NRCS (2021a) *Cardaria draba* (L.) Desv. United States Department of Agriculture, Natural Resources Conservation Services. https://plants.usda.gov/core/profile?symbol=cadr. Accessed March 3 2021

USDA-NRCS (2021b) The plants database. United States Department of Agriculture, National Resources Conservation Service. https://plants.usda.gov/core/profile?symbol=CADR. Accessed 23 February 2021

van der Ent A, Baker AJM, Reeves RD, Pollard AJ, Schat H (2013) Hyperaccumulators of metal and metalloid trace elements: facts and fiction. Plant Soil 362:319-334 van Kleunen M et al. (2015) Global exchange and accumulation of non-native plants. Nature 525:100-103

van Klinken RD (2000) Host specificity testing: why do we do it and how we can do it better. In: Van Driesche R, Heard T, McClay A, Reardon R (eds) Proceedings, host specificity testing of exotic arthropod biological control agents: the biological basis for improvement in safety, X international symposium on biological control of weeds, Bozeman, Montana, USA, 1999. Forest Health Technology Enterprise Team, pp 54-68

von Rütte J (2013) BIOCONTROL: POSSIBLE REASONS FOR SUCCESS. Thesis, University De Fribourg

Wall MA, Boyd RS (2006) *Melanotrichus boydi* (Hemiptera: Miridae) is a specialist on the nickel hyperaccumulator *Streptanthus polygaloides* (Brassicaceae). Southwest Nat 51:481-489

Warner DW, Case T, Ricks B (2018) Total recoverable elements: Acid digestion of sediments, sludges, and soils. Analytical sciences laboratory standard methods by regents of the University of Idaho SMM 35:1-6

Weidenhamer JD, Callaway RM (2010) Direct and indirect effects of invasive plants on soil chemistry and ecosystem function. J Chem Ecol 36:59-69

Weyl P, Closça C, Hinz HL, Besomi G (2019a) Biological control of whitetops, *Lepidium draba*, *L. chalepense* and *L. appelianum.* Annual report, unpublished. CABI, Delémont, Switzerland

Weyl P, Closca C, Hinz HL, Mathias C, Taylor L (2019b) Biological control of whitetops, *Lepidium draba*, *L. chalepense* and *L. appelianum*. Annual report, unpublished. CABI, Delémont, Switzerland

Whittaker RH (1954) The ecology of serpentine soils. Ecology 35:258-288

Williams H, Neser S, Madire L (2008) Candidates for biocontrol of Macfadyena unguis-cati in South Africa: biology, host ranges and potential impact of Carvalhotingis visenda and Carvalhotingis hollandi under quarantine conditions. BioControl 53:945-956

Williamson M, Fitter A (1996) The varying success of invaders. Ecology 77:1661-1666

Winston RL, Schwarzländer M, Hinz HL, Day MD, Cock MJW, Julien M (2014) Biological control of weeds: A world catalogue of agents and their target weeds. 5th edn. Forest Health Technology Entreprise Team, Morgantown, West Virginia

Winston RL, Schwarzländer M, Hinz HL, Day MD, Cock MJW, Julien MH (eds) (2022) Biological control of weeds: A world catalogue of agents and their target weeds (Web version). Based on FHTET-2014-04, USDA Forest Service, Forest Health Technology Enterprise Team. Available at https://www.ibiocontrol.org/catalog/index.cfm.

Zalucki MP, Van Klinken RD (2006) Predicting population dynamics of weed biological control agents: science or gazing into crystal balls? Aust J Entomol 45:331-344

Table 3.1 Result of generalized linear mixed model ANOVA of plant performance traits: Total leaves, longest leaf length and aboveground dry biomass for target weed and the nontarget plant species grown in both, potting and serpentine soil

Effects	Plant performance traits								
	Total leaves			Leaf length			Aboveground dry biomass		
	df(num., den)	*F*	*P*-value	*df*(num., den)	*F*	*P*-value	*df*(num., den)	*F*	*P*-value
Soil type	1, 21	43.47	<0.0001	1, 149	923.08	<0.0001	1, 149	797.97	<0.0001
Plant species	3, 21	10.43	0.0002	3, 149	47.49	<0.0001	3, 149	30.45	<0.0001
Soil type × Plant species	3, 21	0.63	0.6067	3, 149	28.59	<0.0001	3, 149	33.47	<0.0001

Significance of effects at $P \leq 0.05$

Table 3.2 Generalized linear mixed model ANOVA on *Ceutorhynchus cardariae* herbivory and development (proportion leaves with feeding and leaf area consumed) for target weed and the nontarget plant species grown in both, potting and serpentine soil

Effects	*Ceutorhynchus cardariae* feeding and development					
	Proportion leaves fed			Leaf area consumed		
	df(num., den)	*F*	*P*-value	*df*(num., den)	*F*	*P*-value
Soil type	1, 21	4.69	0.0420	1, 149	30.81	<0.0001
Plant species	3, 21	14.07	<0.0001	3, 149	1.43	0.2370
Soil type ×Plant species	3, 21	1.88	0.0645	3, 149	1.80	0.1499

Significance of effects at P ≤0.05

Table 3.3 Zero-inflated negative binomial model on number of *Ceutorhynchus cardariae* galls developed for target weed and the nontarget plant species grown in both, potting and serpentine soil

Effects	No. of galls developed		
	df	χ^2	*P*-value
Soil type	1	49.74	<0.0001
Plant species	3	30.16	<0.0001
Soil type × Plant species	3	5.07	0.1665

Significance of effects at P ≤0.05

Fig. 3.1 Plant parameters for *Lepidium draba* and *Caulanthus anceps, C. flavescens, and C. inflatus* grown in potting soil and serpentine soil; a) number of leaves per plant; b) longest leaf length per plant; and c) aboveground dry biomass per plant. For the latter two traits, interaction plots were used to illustrate the significant interaction between soil type and plant species (P <0.05, pairwise mean comparison). Bars are means (SE)

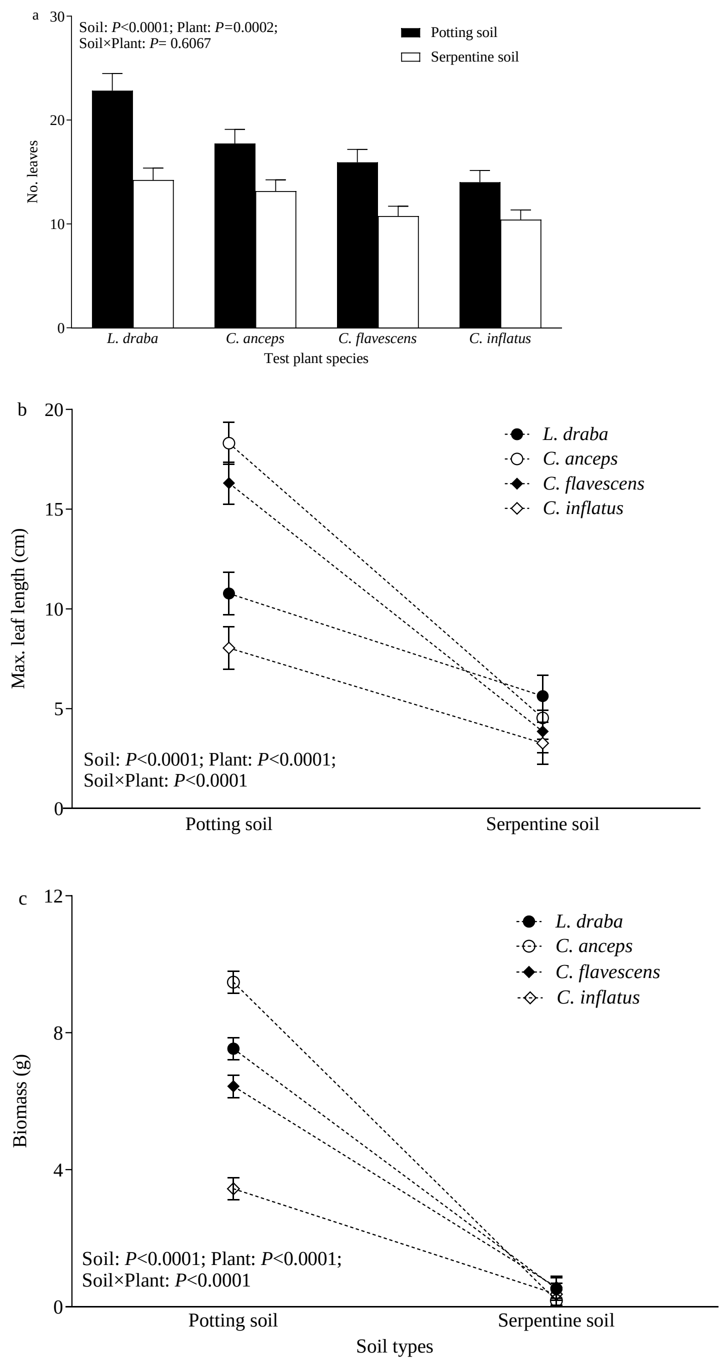


Fig. 3.2 *Ceutorhynchus cardariae* herbivory on *Lepidium draba, Caulanthus anceps, C. flavescens, and C. inflatus* plants grown in potting soil or serpentine soil; a) proportion leaves per plant with feeding marks; and b) leaf area consumed per plant. Bars are means (SE)

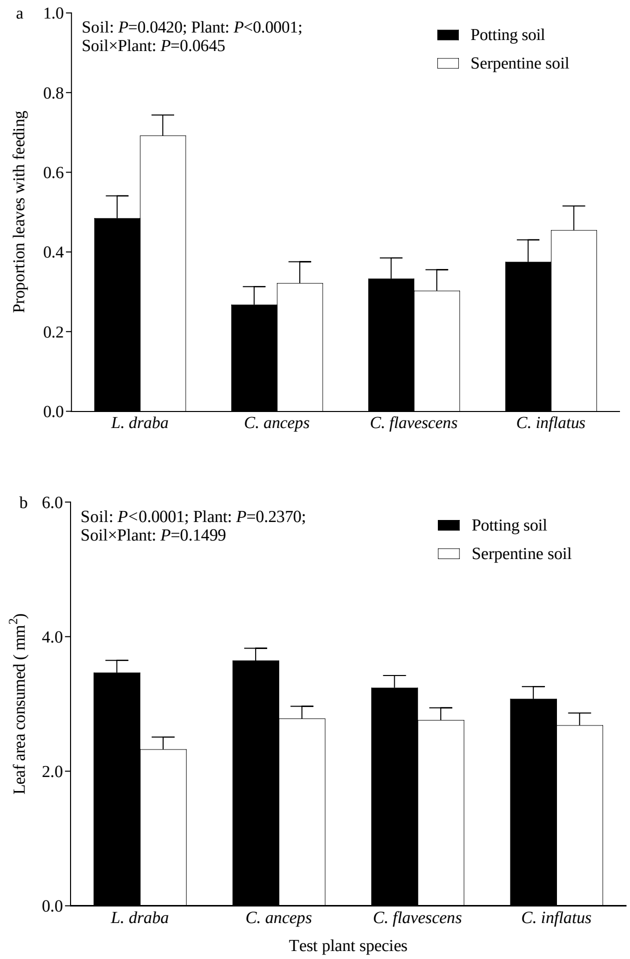
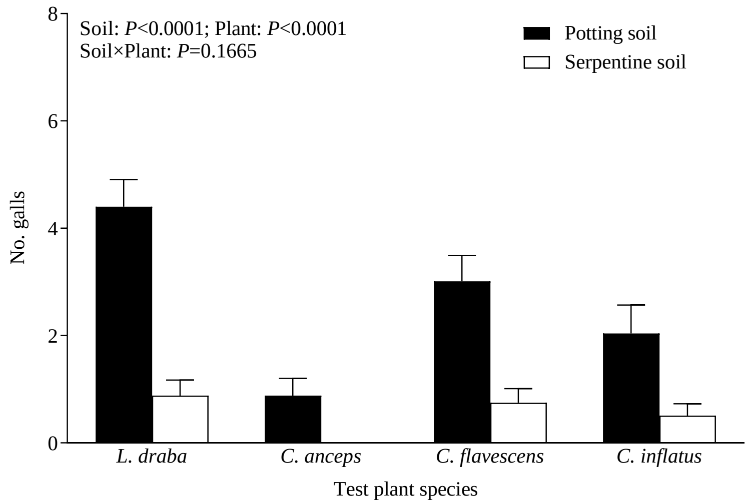


Fig. 3.3 Number of *Ceutorhynchus cardariae* galls developed on *Lepidium draba, Caulanthus anceps, C. flavescens, and C. inflatus* grown in potting and serpentine soil. Bars are means (SE)



Appendices

Appendix E No-choice gall development and adult emergence tests with *Ceutorhynchus cardariae* conducted at CABI, Switzerland between 2003 and 2019 (Source: *C. cardariae* petition, unpublished, M. Schwarzländer et al.). No. of galls and adults are mean ± SE

Plant species	No of plants exposed	No of plants with galls	Mean galls per plant	Mean adults per plant
Lepidium draba	128	113	7.1 ± 0.7	11.0 ± 1.5
Caulanthus anceps	46	41	4.6 ± 0.5	2.1 ± 0.5
Caulanthus flavescens	41	39	6.1 ± 0.5	4.6 ± 1.1
Caulanthus inflatus	80	41	1.6 ± 0.3	1.0 ± 0.3
Streptanthus glandulosus subsp. *albidus*	7	6	2.7 ± 0.9	0.1 ± 0.1

Appendix F Elemental analysis of field-collected serpentine soil and laboratory prepared standard potting soil. For elemental analysis, n=4 per soil type. Element concentrations are mean ± SE. Means for an element with differing superscript indicate a significant difference at $P \leq 0.05$

Elements ($\mu g\ g^{-1}$)	Soil	
	Potting soil	Serpentine soil
Phosphorous (P)	2,100.00 ± 129.10[a]	129.53 ± 105.95[b]
Potassium (K)	2,525.00 ± 197.38[a]	104.65 ± 51.66[b]
Magnesium (Mg)	4,675.00 ± 286.87[a]	132,539.66 ± 16246.61[b]
Calcium (Ca)	19,250.00 ± 853.91[a]	1,281.85 ±753.42[b]
Cobalt (Co)	5.28 ± 0.28[a]	158.39 ± 22.62[b]
Chromium (Cr)	12.30 ± 1.95[a]	1,369.46 ± 268.15[b]
Copper (Cu)	19.25 ± 0.63[a]	39.31 ± 3.86[b]
Iron (Fe)	8,775.00 ± 658.76[a]	81,791.00 ± 9874.77[b]
Manganese (Mn)	240.00 ± 7.07[a]	1,566.16 ± 250.31[b]
Nickel (Ni)	7.90 ± 0.70[a]	2,970.50 ± 607.13[b]
Zinc (Zn)	57.75 ± 3.35[a]	31.78 ± 1.92[b]
Ca: Mg ratio	4.13 ± 0.09[a]	0.01 ± 0.01[b]

Appendix G Total elemental analysis of plant tissue grown on serpentine and standard potting mix soil. Plant tissue metal concentrations are µg per g dry mass of plants

Elements $\mu g\ g^{-1}$	Plant Species								Concentrations range*
	Lepidium draba		*Caulanthus anceps*		*Caulanthus flavescens*		*Caulanthus inflatus*		
	PS	SS	PS	SS	PS	SS	PS	SS	
Calcium (Ca)	23000	6600	25000	7200	36000	9800	46000	15000	1000-50000
Potassium (K)	81000	14000	47000	27000	81000	26000	82000	34000	5000-34000
Magnesium (Mg)	4600	9700	4700	16000	4900	13000	6200	19000	1000-9000
Phosphorous (P)	9100	2500	13000	6700	10000	5900	11000	8300	120-30000
Aluminum (Al)	<20	1300	<20	810	23	240	<20	250	90-530
Chromium (Cr)	<2.0	36.0	<2.0	34.0	<2.0	12.0	<2.0	8.8	0.2-1.5
Copper (Cu)	6.0	5.2	5.7	7.2	8.7	5.7	5.3	7.2	2-20
Iron (Fe)	73	1500	61	1800	70	740	86	710	5-200
Manganese (Mn)	130	41	46	48	98	42	54	73	1-700
Nickel (Ni)	<2.0	36.0	<2.0	74.0	2.3	37.0	<2.0	34.0	0.4-10[#]
Zinc (Zn)	270	31	140	73	170	63	240	140	15-150
Ca: Mg ratio	5.00	0.68	5.32	0.45	7.35	0.75	7.42	0.79	1-6

For elemental analysis, n=1 leaves sample/plant species/soil type. Values present with '<' indicates the concentration of the corresponding element at or below detection limits. Ca: Mg ratio calculated by dividing total calcium concentrations by total magnesium concentrations. ***Average concentrations ranges are the typical worldwide element concentrations from all plants reported in the literature (See Dunn 2007; Strawn et al. 2019 and refstherein). [#]Upper limit for nickel concentrations value was reported by Reeves et al., (1981). PS = potting soil mixture and SS =serpentine soil (see materials and methods for details)

Reference

Dunn CE (2007) New perspectives on biogeochemical exploration. Paper 12. Advances in prospect-scale geochemical methods. In: Milkereit B (ed) Proceedings of exploration 07: Fifth decennial international conference on mineral exploration, Toronto, Canada, Sep 9-12, 2007. pp 249-261

Strawn DG, Bohn HL, O'Connor GA (2019) Soil chemistry. 5th edn. John Wiley & Sons Ltd., New Jersey

Reeves RD, Brooks RR, Macfarlane RM (1981) Nickel uptake by Californian *Streptanthus* and *Caulanthus* with particular reference to the hyperaccumulator *S. polygaloides* Gray (Brassicaceae). Am. J. B. 68:708-712

Appendix H The plant species exposed at the rosette stage to *C. cardariae* and the summary of no-choice feeding and development tests conducted at the University of Idaho quarantine facility. Adult emergence includes emerged adult plus live larvae during dissection, while empty galls are where no larvae were found during dissection. PS = potting soil mixture and SS = serpentine soil (see materials and methods for details)

Plant species	Soil type	No. valid replicates	No. plant with galls	No. Galls	No. adult emerged	No. dead larvae in gall	No. empty galls
Lepidium draba	PS	20	19	86	11	30	33
	SS	20	8	13	0	2	10
Caulanthus anceps	PS	20	5	12	1	8	2
	SS	20	0	0	0	0	0
Caulanthus flavescens	PS	20	11	47	1	13	11
	SS	20	8	11	0	4	3
Caulanthus inflatus	PS	20	7	26	0	10	2
	SS	20	4	7	0	4	3
Streptanthus glandulosus subsp. *albidus*	SS	3	1	1	0	0	1