diversity

MDPI

Article

Itching for an Answer: Gall-Forming Biological Control Agent Contains an Itch Mite Species Found at Localities Known for Periodic 'Bite Outbreaks'

Ruan Veldtman [1,2,*], Eddie Ueckermann [3] and Kayla Liebenberg [4]

[1] Kirstenbosch Research Centre, South African National Biodiversity Institute, Private Bag X7, Claremont 7735, South Africa
[2] Department of Conservation Ecology and Entomology, Stellenbosch University, Private Bag X1, Matieland 7602, South Africa
[3] Unit for Environmental Sciences and Management, Potchefstroom Campus, North-West University, Private X6001, Potchefstroom 2520, South Africa
[4] Department of Botany and Zoology, Stellenbosch University, Private Bag X1, Matieland 7602, South Africa
* Correspondence: veldtman@sun.ac.za

Abstract: Biological control is an attractive option for controlling invasive plant species that are difficult to manage otherwise. However, the release of a non-native species as a biological control agent carries risks. The most obvious risk relates to impacts on plant species other than the plant species targeted for control. There are, however, also other risks. We report on a potential unintended impact of *Dasineura dielsi*, a gall-forming biological control agent that was released against *Acacia cyclops* in South Africa in 2003. We confirmed that the galls formed by *D. dielsi* on *A. cyclops* harbor mites in the genus *Pyemotes* (*P.* cf. *ventricosus*) within their gall structures, which are parasites of various insect species, but are also known to cause dermatitis in humans. Sporadic biting incidences have been reported in at least two locations in South Africa. The implications are that manual clearing of *A. cyclops* may expose humans to itch mites and to risks of bites. Gall-forming insects and fungi are known to create niches for herbivores and other gall-associated fauna. Although every possible food web interaction cannot be predicted, enough evidence exists to require that agent screening to include non-target risks other than those pertaining to non-host plants. Testing only whether agents are compromised by interactions with non-target plant species is not sufficient during agent evaluation. If such associations are known from the native range and therefore can form in the introduced range, then any known risk to health and socio-economic activities should be disclosed. We argue for the general development of objective assessment of such risks compared with the benefits potentially accruing from successful biological control of the target plant.

Keywords: Australian Acacia; non-target impacts; plant–insect interactions

check for updates

Citation: Veldtman, R.; Ueckermann, E.; Liebenberg, K. Itching for an Answer: Gall-Forming Biological Control Agent Contains an Itch Mite Species Found at Localities Known for Periodic 'Bite Outbreaks'. *Diversity* **2023**, *15*, 73. https://doi.org/10.3390/d15010073

Academic Editors: Michael Wink, Luc Legal, Ben-Erik Van Wyk and Michel Baguette

Received: 14 November 2022
Revised: 30 December 2022
Accepted: 5 January 2023
Published: 6 January 2023

Copyright: © 2023 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (https://creativecommons.org/licenses/by/4.0/).

1. Introduction

Classical biological control involves the deliberate introduction and release of exotic yet host-specific agents (e.g., insects, mites, pathogens, etc.) on targeted invasive species, which have the potential to provide long-term control [1,2]. While some agents or "natural enemies" target the vegetative structures of invasive alien weeds, others reduce fecundity by attacking reproductive structures [1,3,4].

Initially, ecological concerns of introducing weed biological control agents (i.e., herbivores) focused on direct non-target effects [5–8], but more recent studies suggest that unintended impacts can extend far beyond the primary host–control agent interaction [9,10]. Indirect non-target impacts can include direct [11], and apparent competition [12]. Through such indirect effects, even the introduction of highly host-specific biological control agents can have ramifications for recipient native ecosystems [12,13].

Weed biological control agents that are gall-formers are considered low risk because they are usually host species-specific, and therefore unlikely to attack non-target hosts [1]. One group in particular, the seed biological control of invasive Australian Acacia (wattles) is a lauded example of success which has been a major focus in invasive alien management in terms of effort and funding [3,14,15]. However, gall formers change the architecture of the plant, and can create resources that are then available for invertebrates that are inquilines [16,17], and so can be considered to act as ecosystem engineers [18–20]. Gall-producing weed biological control agents can thus create a novel resource for indigenous invertebrates feeding on gall tissue [9]. Another drawback is that when the weed is abundant and the agent is not able to reduce it, the galling biological control agents can become superabundant and have great potential to subsidize food webs with additional resources for parasitoids or predators of native insect herbivores [12,21–23].

Australian Acacias are invasive species that have severe transformative impacts in many parts of the world [24]. These species have a long-lived seedbank that makes mechanical control efforts difficult [25,26]. In South Africa, several biological control agents have been introduced to reduce seed output without damaging non-reproductive parts of the target plant, with the aim of limiting spread without compromising cultivation of beneficial species [27]. In the case of *Acacia cyclops* (rooikrans) in South Africa, the release in 1994 of the seed-attacking weevil *Melanterius servulus* Pascoe (Coleoptera: Curculionidae) achieved sparse establishment and limited seed reduction potential due to short-distance dispersal [4,28]. The release of the mobile flower-galling midge *Dasineura dielsi* Rübsaamen (Diptera: Cecidomyiidae) (Figure 1) in 2003 resulted in widespread establishment and dramatic seed reduction by inducing abnormal ovarian growths (i.e., "galls") in the florets via oviposition [28,29]. Biological control of *A. cyclops* is currently regarded as successful and a good example of ideal control [14] although the ecological evidence for such control has been questioned for three other *Acacias* under similar biological control [26,30].

Figure 1. (**A**) Adult *Dasineura dielsi* (lateral view) on an *Acacia cyclops* inflorescence. (**B**) Intact *A. cyclops* seed pods, which encase black oval-shaped seeds with distinctive red funicles. (**C**) Gall cluster resulting from *D. dielsi* oviposition, whereby the ovary wall evaginates from the resultant larvae feeding and this prevents seed production of the inflorescence [31]. Adult midges then emerge from the ostioles (i.e., emergence holes) observed along the gall cluster. ©Kayla Liebenberg.

There are reports of people living in small coastal towns plagued by itch bite outbreaks which are situated close to *A. cyclops*-dominated plant communities where *D. dielsi* galls are found [32,33]. In a monthly report of the Fransmanshoek Conservancy (southern coast of the Western Cape Province of South Africa), it was reported that first *D. dielsi* was suspected of being responsible for these bites and later its associated parasitoid wasp species, due to the abundance of galls in the landscape and bites occurring when people interact with *A. cyclops* trees [32]. This explanation was initially ruled out by Prof. Henk Geertsema who suggested that house mites from another source are probably responsible for the itching bites. Subsequently, gall material near the offices of the Fransmanshoek Conservancy was collected by Kei Heyns on 3 April 2019 from the same vicinity of the 2017 bite outbreak and sent to one of the authors (RV) from which six species of mites were extracted by M. Vermaak. This indicated that mites are indeed occupying the galls formed by *D. dielsi* in this coastal locality. Another community in Shelley Point (west coast of the Western Cape Province) reported in a newsletter that itch mites were thought to be responsible for biting people from some 'certain vegetation' [33]. However, both communities live in an *A. cyclops*-infested habitat currently under biological control by *D. dielsi*. A review of the biological control literature revealed that Impson et al. [31] described the presence of itch mites of the genus *Pyemotes* from galls formed by *D. dielsi*. Their anecdotal observations indicated that these mites are predators of the gall midge but that periodic "outbreaks" of these mites were not consistent and that *D. dielsi* populations would not be negatively affected. Similar published studies have documented mites living in *Dasineura strobila* galls on *Leptospermum laevigatum* also found invading terrestrial ecosystems near the coast [34,35]. Mite outbreaks associated with gall-forming biological control agents are thus not uncommon and have been linked to warmer, more humid weather conditions [35,36].

In this study we aimed to describe the mite species associated with *D. dielsi* galls from localities with *A. cyclops*-dominated vegetation. We were also specifically interested to identify mite species capable of biting humans, in the galls of *D. dielsi*. We aimed to sample across the distribution of *A. cyclops*, focusing on areas where 'bite' outbreaks have been reported.

2. Materials and Methods

Study Sites

For our study, we targeted two areas that are known for periodic itch bite outbreaks, namely Fransmanshoek Conservancy and Shelley Point [32,33]. Sampling was undertaken at the following sites: Shelley Point (SP) (SP1, 32°43′01″ S, 17°58′09″ E; SP2, 32°43′04″ S, 17°58′27″ E; SP3, 32°42′52″ S, 17°58′41″ E); Fransmanshoek Conservancy (FC) (FC1, 34°17′45″ S, 18°27′28″ E; FC2, 34°17′56″ S, 21°55′09″ E; FC3, 34°17′45″ S, 21°54′55″ E); and one random locality where *A. cyclops* and *D. dielsi* galls were abundant, namely the Melkbosstrand Conservation Area (MKB1, 33°42′31″ S, 18°27′07″ E; MKB2, 33°42′39″ S, 18°26′54″ E; MKB3, 34°18′01″ S, 21°54′57″ E).

Between 24 April and 19 May 2021, each study site was assigned a one- or two-day sampling effort (i.e., SP: 24 April; FC: 1–2 May; MKB: 19 May) to sample 15 trees per site, which led to a combined total of 45 mature *A. cyclops* trees with flowers and galls being sampled. We selected trees that were at least 2 m tall, had a basal stem diameter of at least 9 cm, and had at least 100 galls [28]. Subsequently from the 15 trees per site, 5 galls were selected. From these 5 galls, the presence of mites and their identity were determined. Therefore, a total of 225 galls per site can yield any number of mites and other insects.

Our sampling coincided with the mid-summer/early autumn peak in *A. cyclops* flowering phenology [28]; the attainment of maximum gall densities on host plants between March and June [28]; and the time period in which reports of "bites" increase at Fransmanshoek Conservancy (February–April) and Shelley Point (February–March) [32,33]. Each study site consisted of three pre-selected sample points 500 m apart to ensure independence [19,37]. The total number of trees per sample point were then estimated and five trees (at least 25 m apart) were randomly selected to be visually inspected for galls over a period of 10 min [28]. These selected trees also had their tree height and gall loads (i.e., both mature and senescent loads) estimated, their GPS co-ordinates and elevation values recorded using a handheld GPS, and their basal stem diameter measured [19,28].

Sterilized pruning shears were used to cut five golden-yellow mature gall clusters (diameter: >15–25 mm; branch segment: 5 cm below gall cluster) from the branches of each tree [9]. Due to the unpredictability of pupae emerging as adults, collected gall clusters were immediately stored in separate rearing cages sterilized with 70% ethanol [38]. Five cuttings from each tree were placed into a cylindrical 1 L container with green oasis foam at the bottom to stabilize the cuttings; and covered with fine, ventilated mesh cloth (dimensions: 30 × 22 cm) fixed with an elastic band to allow ventilation but trapping emerging invertebrates [39].

A shake-and-wash mite extraction technique described by Pratt et al. [40] was also used to evaluate mite diversity in the field. Each location was divided into three sample points that were 500 m apart to ensure independent sampling and then 5 trees (at least 25 m apart) were randomly selected per sample point [19,37]. For each study point at a particular location, 5 galls with ostioles (openings on the gall tube) were trimmed and placed into a 350 mL container filled with 100 mL of 70% ethanol. These containers were fastened with air-tight lids before being manually shaken for 30 s, left to settle for one minute, and then shaken again for another 30 s [40]. Preserved mites that consequently settled at the bottom of the container were then processed in the laboratory by KL using a binocular stereoscope 40X magnification (described below) [40,41]. All extracted mites were then placed into morphospecies-specific Eppendorfs filled with 5 mL of 70% ethanol and were identified by EU. All oribatid mites were lodged at the National Museum of Bloemfontein for identification by Dr. Lizel Coetzee Hugo.

In the laboratory, the galls (n = 15 per study site) used in the ethanol wash were stored in a fridge and later dissected using a sterilized scalpel [28]. This provided insight into the insect diversity hosted within the galls in addition to the prevalence of mites within these galls [12,28]. It was confirmed that both midge larvae and mites were recovered from the hollow chambers of the galls.

The permanent mounting of mites onto microscope slides was performed using PVA following the methods described by Ueckermann and Grout [42]. Mounted mite specimens were dried in an oven at 45–50 °C for 24 h and examined under a Zeiss Axioskop TM Research microscope [43]. In addition, RV provided slides of mites mounted with Hoyer's solution [44] that were retrieved from an ethanol wash conducted at Fransmanshoek Conservancy during April 2019 (the period in which "itch" bites spiked [32]). The slides were compared with the recently collected mite specimens. It was confirmed that several of the same mite species were recovered, including *Pyemotes* cf. *ventricosus*.

3. Results

Across the 45 *Acacia cyclops* trees sampled from the three study sites, a total of 460 mite specimens comprising of 18 morphospecies were recovered from 594 gall clusters (i.e., 45 galls washed in ethanol + 549 galls used for rearing). From this, *Pyemotes* cf. *ventricosus* specimens were retrieved (Figure 2), while three new mite species were identified and several other mite species were recovered (see Table 1). In addition, gall dissections confirmed these mites to be present inside the individual galls of a cluster based on the cohort of galls that were dissected.

Table 1. Native mite species extracted from *Dasineura dielsi* galls collected from *Acacia cyclops* trees in the Western Cape of South Africa. These mite species were recovered from both rearing cages and the ethanol wash experiment. Feeding guild was assigned based on published literature where possible.

Family (/Order)	Species	Feeding Guild [a]	Total Abundance
Trombidiformes			
Pyemotidae	*Pyemotes* cf. *ventricosus*	Parasitic [45,46]	91
Tarsonemidae	*Tarsonemus* sp.	Fungivorous *	47
	Tarsonemus waitei	Fungivorous [47]	4
Tydeidae	*Tydeus grabouwi*	Generalist [42]	22
	Genus indet.	unknown	15
Iolinidae	*Lourus* sp. *	Predatory [48]	2
	Pausia sp. *	Predatory [48]	19
Adamystidae	*Adamystis* sp. *	Predatory [49]	6
Triophtydeidae	*Triophtydeus immanis*	Generalist [50]	15
Sarcoptiformes			
Acaridae	*Tyrophagus fanetzhangorum*	Mycophagous	4
Winterschmidtiidae	*Acalvolia* sp.	Mycophagous [50,51]	203

Table 1. *Cont.*

Family (/Order)	Species	Feeding Guild [a]	Total Abundance
Cheyletidae	Genus indet.	Predatory [50]	2
Mesostigmata			
Phytoseiidae	*Typhlodromus* (*Anthoseius*) sp.	Predatory [52]	2
	Ueckermannseius munsteriensis	Predatory [50]	4
Family indet.	Genus indet.	unknown	1
Oripodidae	*Dometorina* (*Siculobata*) *sicula* [b]	Mycophagous [53]	4
	Dometorina (*Dometorina*) *plantivaga* [c]	Mycophagous, predatory [53]	8
Ceratozetidae	*Antarctozetes* sp. [d]	Mycophagous, detritophagous, necrophagous [53]	2

[a] Feeding guild of mites were categorized as 'parasitic', 'predatory' (i.e., prey on other mites), 'mycophagous', 'detritophagous', 'necrophagous', 'fungivorous', and 'generalist' (i.e., feed on pollen, fungi, and predatory). All oribatei mites were lodged at the National Museum of Bloemfontein and the accession numbers were provided. [b] NMB4726, NMB4728, NMB4729; [c] NMB4727, NMB4732, NMB4733; [d] NMB4730, NMB4731. * Mite species indicated with an asterisk are new to science.

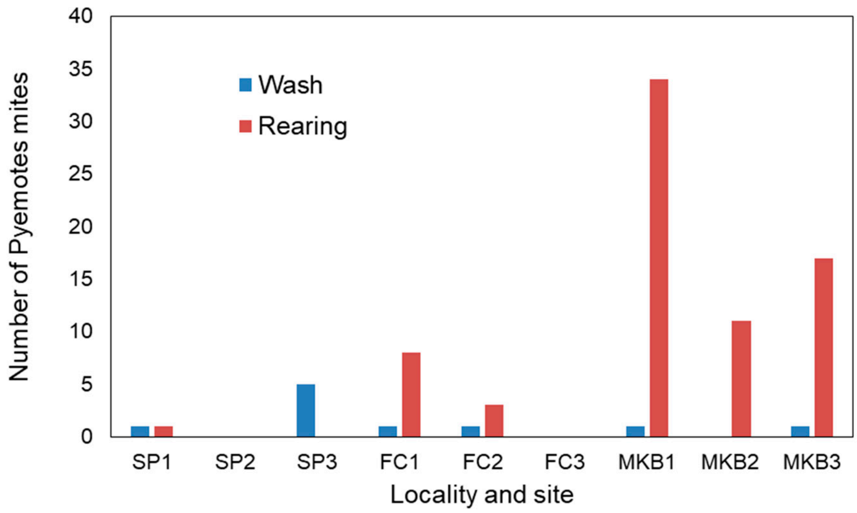

Figure 2. Number of *Pyemotes* cf. *ventricosus* mites counted and sites of sample localities, comparing the ethanol wash and gall rearing method (see Materials and Methods).

We found mites of several species across the three sites we sampled per locality which indicates both rare and abundant taxa (Table 2). There were 1 to 7 species of mite found at a locality and the rearing boxes yielded more mites that the ethanol wash method.

Table 2. Mite community data matrix (sampling sites by species abundance) across feeding guilds and locations situated in the Western Cape, South Africa. Columns labelled, "Sampling sites" indicate total captures per mite species for the ethanol wash experiment. Any additional mite specimens retrieved from the rearing experiments were indicated in brackets. SP—Shelly Point; FC—Fransmanshoek Conservancy; MKB—Melkbosrtrand.

Feeding Guild	Sampling Sites								
Species	SP1	SP2	SP3	FC1	FC2	FC3	MKB1	MKB2	MKB3
Parasitic									
Pyemotes cf. *ventricosus*	1(1)	0	5	1(8)	1(3)	0	1(34)	0(11)	1(17)
Fungivorous									
Tarsonemus sp.	3	0	1	3(9)	2(2)	0(16)	0(2)	0(4)	3
Tarsonemus waitei	0	0	0	0	0	0	4	0	0
Generalists									
Triophtydeus immanis	0	1	3	0	0	0	0(1)	0(6)	4
Tydeus grabouwi	1(1)	1	0	0(3)	7	0	0	0	1

Table 2. *Cont.*

Feeding Guild	Sampling Sites								
Species	**SP1**	**SP2**	**SP3**	**FC1**	**FC2**	**FC3**	**MKB1**	**MKB2**	**MKB3**
Mycophagous									
Acalvolia sp.	0	0	0	54(41)	35(13)	0(36)	0(4)	0(5)	0
Dometorina (Siculobata) sicula	0	0	0	0(1)	1	2	0	0	0
Tyrophagus fanetzhangorum	0	0	0	0	0(1)	0(3)	0	0	0(1)
Mycophagous, predatory									
Dometorina (Dometorina) plantivaga	0	6	1	0	0	0	0	0	0
Mycophagous, detritophagous, necrophagous									
Antarctozetes sp.	0	0	0	0(1)	0	0	0	1	0
Predatory									
Adamystis sp. *	0	0	0	0(3)	0(1)	0(1)	0	0	0
Cheyletidae	0	0	0	0	0	0	1	0	0(1)
Lourus sp. *	0	0	0	0(1)	0	0	0	0	0
Pausia sp. *	2	1	6	0	0	0	2(4)	0(1)	1(2)
Typhlodromus (Anthoseius) sp.	0	0	0	0	0	0	0	1	1
Ueckermannseius munsteriensis	0	0	0	1	3	0	0	0	0
Unknown									
Tydeidae	0(1)	0	0	0	0	0	7(5)	0	1
Species richness	4(3)	4	5	4(6)	6(5)	1(4)	5(5)	2(5)	7(4)
Total abundance	7(3)	9	16	59(25)	49(20)	2(55)	15(41)	2(27)	11(21)

All mite species indicated with an asterisk (*) are new to science.

4. Discussion

Here we show that *D. dielsi* galls harbor a diverse mite community associated with the galls, including three species new to science and one species of *Pyemotes* (confirming the anecdotal observation of Impson et al. [31]). Worldwide there are about 20 species of *Pyemotes* described [54] with this genus being split into the *scolyti* and *ventricosus*, some species in the latter are known to have venom [55]. However, species identification resulted in this species being classified as *Pyemotes* cf. *ventricosus* or the straw itch mite (a full species identification cannot yet be made due to the absence of male mites required for morphological species identification). *Pyemotes* mites are very small (85–325 microns) with males being smaller than females. All offspring are born as sexually mature adults, of which 95–99% are females [54]. This may explain why males were rare in our study.

Species of the genus *Pyemotes* are known globally to be responsible for incidental bites on humans, which can cause severe allergic reactions which in extreme cases lead to hospitalization [45,56,57]. Broce et al. [45] actually discovered that a human itch bite outbreak was caused by *Pyemotes herfsi*, feeding of the oak galler *Contarinia* sp. in North America. These mites, which feed on midge larvae by injecting them with an immobilizing neurotoxin paralyses the larvae and allows the mite to feed on the static larvae. This same toxin can induce lesions in humans consisting of an urticarial papule capped with a very small vesicle [45,56]. These authors carefully searched a range of habitats with several sampling methods, however, the leaf roll galls caused by gall midge which larvae created prey and habitat for *P. herfsi*. The genus *Pyemotes* has the characteristic of searching for hosts that are found in protected habitats such as inflorescences, beetle galleries and galls. It was Impson et al.'s [31] observation that the galls of *D. dielsi* create an ideal habitat for *Pyemotes* mites which also undergo periodic "outbreaks" during preliminary monitoring (reported as unpublished data).

This species can thus incidentally fall on humans passing through or working within *A. cyclops* populations. Itch bite outbreaks can be exacerbated when mites are dispersed by wind into human dwellings as reported by Shelley Point residents whose houses are surrounded by *A. cyclops* trees [33]. *Pyemotes herfsi* was documented as ballooning into houses from galled oak trees by Broce et al. [45]. The two reports of outbreaks are difficult to track, because "itch bite" incidents are more prominent during certain months, at specific locations, and "itch bite" symptoms can vary in severity based on the individual's allergic reaction to the injected neurotoxin [45]. Furthermore, there is the challenge of finding non-gravid female mites biting humans because the painless process of being bitten masks the 16 h window to observe bites manifesting, and the temporal irregularity of these outbreaks [45]. *Pyemotes* mites are commonly referred to as itch mites because their tendency to 'bite' with stylet mouthparts [57,58] are considered worse than vertebrate parasitic mites which have pinching mouth parts which they use to access a blood meal [59–61]. It was also interesting to find *P.* cf. *ventricosus* within the Fransmanshoek Conservancy gall samples from 2019, the same "itch bite" outbreak locality reported by Blignaut et al. [32]. Although we have no direct evidence that *P.* cf. *ventricosus* is responsible for the "itch bite" outbreaks experienced by residents in these localities (i.e., sampled from the skin of affected persons) (see also Broce et al. [45] which also could not directly link the mites from galls and residents being bitten), the anecdotal reports of shared "itch bite" symptoms [32,33] and the presence of only one *Pyemotes* mite species in association with *A. cyclops* previously also described as having periodic outbreaks [31], provides compelling evidence that this species living in the *D. dielsi* galls is indeed responsible for human bites.

We propose several avenues for future research in this system: (i) to conduct experiments (with necessary ethical clearance) to confirm the suggested link between dermatitis caused by *Pyemotes* mites experienced by residents in close contact with *D. dielsi* galls in *A. cyclops* stands (specifically the two regular outbreak areas); (ii) to investigate whether similar mite communities can be obtained from similar gall structures made by other gall midges used for biological control, e.g., *Dasineura rubiformis* galls on *Acacia mearnsii* [62] and *Dasineura strobila* galls on *Leptospermum laevigatum* [33,63]; (iii) to determine why "itch bite" outbreaks are more pronounced in certain years (i.e., [32]); and (iv) to identify the factors underlying this spatio-temporal variation in mite richness and abundance to further investigate why these "itch bite" outbreaks are localized events and tend to occur during specific months (February–April at Fransmanshoek Conservancy and February–March at Shelley Point respectively; [32,33]). The authors are also currently investigating the diversity of insects associated with *D. dielsi* galls on *A. cyclops* in the same system, which includes a rich fauna of parasitoids and inquilines interacting with the gall (Liebenberg et al. unpublished). In summary, the native fauna associated with *D. dielsi* and its invasive host is a diverse multi-faceted system which requires more investigations to enhance our understanding of these novel interactions.

What is the significance of finding a harmful species associated with a released gall-forming biocontrol agent, i.e., a genus known to bite humans firmly established as living in the galls of the biological control agent [31]? Firstly, this is another study providing evidence that galls form habitats for a local species and has a potential cost for humans. Seymour and Veldtman [19] found that the false codling moth (*Thaumatotibia leucotreta*), a major pest of citrus crops, occurs and completes its development in the galls of the agent *Uromycladium morrisii* (formerly *U. tepperanium*), the gall-forming agent released on *Acacia saligna*. When these trees occur next to citrus orchards these galls provide an additional niche and potential source for this pest [19]. Similarly, galls of *Trichilogaster acaciaelongifoliae* released in 1982 on *A. longifolia* were found to contain, amongst several other inquilines [9], the litchi moth (*Cryptoplebia peltastica*) which is a known pest of several tree crops. These associations by species of the same families (e.g., Tortricidae) are also found in the native range [9], and it has been proposed that investigating ecological interactions before release of galling agents can identify potentially problematic non-target associations. Pearson et al. [64] recently developed an assessment framework to identify how deliberate species introductions (such as biological control agents) and eradication actions can affect the receiving communities. They show that by doing a basic ecology interaction web, 'surprising' non-target effects can be identified prior to species introductions.

The field of weed biocontrol has gone to great lengths to minimize direct non-target impacts of biocontrol agent release (herbivore agents not interacting with native plants) [65]. However, concerns of indirect non-target risks are not sufficiently considered with very little pre-release investigations (see [23] as a rare example where a native gall community is studied before the release of a gall-forming biological control agent). Galls in particular have been mentioned to increase the chances of indirect non target interactions [19]. In the case of galling biological control agents, low direct non-target impacts may come at the expense of high indirect non-target impacts. More caution should proceed in the selection and use of galling agents, making use of ecological principles [19,64]. At all times, beneficiaries of released agents should be made aware of the potential consequences of such non-target effects and not simply the potential benefits of control. It has been argued that the risk of the invasive plant should be compared with the risk of the release of the biological control agent to improve a risk averse strategy to biological control [66]. However, as we show here for galling agents, the potential associations with non-target species are to a certain extent predictable and any level of study prior to release would be informative on the actual risk posed by release of the agent.

5. Conclusions

We found a species-rich mite community associated with the galls of *D. dielsi*, released to control *A. cyclops* which included *Pyemotes* cf. *ventricosus*. Impson et al. [31] stated that the rich community of invertebrates associated with the galls of *D. dielsi* is not surprising given the complex structure and abundance of the gall resource. Biological control prizes the host specificity, ready establishments, rapid spread, and high abundance of their released agents. However, in the case of galling agents such as those in Australian wattle biological control in South Africa (and now also Portugal based on the reported South African success), this transforms plant–insect sterile biomass into a major biomass of plant–insect interaction [67,68], providing the foundation for a multitude of higher trophic interactions. Thus, investigations in the native range of the insect can possibly show that galls are inhabited by *Pyemotes* mites (itch mites) [9], but seeing as the survival of the agent is the main focus (e.g., [31]), the possible ramifications of this indirect non-target association have not been considered. Consider for a moment that *A. cyclops* leaves and branches are a desert for mites subject to desiccation and high solar radiation. However, with the addition of *D. dielsi*, the sterile biomass of *A. cyclops* is transformed in an 'oasis' with convoluted surfaces that provide refuge (and prey) for mites which they can reproduce in. In this first scientific report of *Pyemotes* cf. *ventricosus* mites are present in *D. dielsi* galls at localities where there has been itch bite outbreaks, where residents also referred to "muggie tyd", translated to midge season. As we show through several correlative results in this study, it is likely that galls on *A. cyclops* galls elevated the abundance of itch mites in the study area. Even the mere possibility that a released biocontrol agent can provide a habitat for a biting mite is enough to warrant better consideration of potential ecological consequences of biocontrol agent release prior to release [23]. If current ecological theory and case studies indicate that such interactions are likely, why do we first need to document a major impact before the potential ecological consequences of release are better investigated? Indirect non-target interactions require more attention and should not be dismissed just because they potentially complicate agent release.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/d15010073/s1.

Author Contributions: Conceptualization and methodology, R.V. and K.L.; investigation, K.L., R.V. and E.U.; formal analysis, K.L.; writing—original draft preparation, R.V. and K.L.; writing—review and editing, E.U.; supervision, R.V.; project administration, R.V. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by The South African Department of Forestry, Fisheries and the Environment (DFFtE), noting that this publication does not necessarily represent the views or opinions of the DFFtE or its employees. The APC was funded by Diversity.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Mite species recovered per tree, site and locality from ethanol wash and rearing experiment are available from Supplementary Materials.

Acknowledgments: We thank Shelley Point Homeowner's Association (SPHOA) and Fransmanshoek Conservancy for study sites, and to Cape Nature and the City of Cape Town Municipality for permits to sample at the Melkbosstrand Conservation Area. Joshua Bransgrove provided assistance with field work. Thanks are also due to the field rangers at Fransmanshoek Conservancy (Erich Goold, Zandré Durand, and Tristan Dedekind), the Agricultural Research Council (ARC) and by Lizel Coetzee Hugo of the National Museum of Bloemfontein for identifying invertebrate specimens. The mounting of slides from 2017 collections was completed by Mia Vermaak. Matthys Strydom and Antoinette Veldtman are respectively thanked for commenting on an earlier and revised draft of the manuscript. Three anonymous reviewers are also thanked for their constructive criticisms.

Conflicts of Interest: The authors declare no conflict of interest. The funder had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, or in the decision to publish the results.

References

1. Cruttwell McFadyen, R.E. Biological control of weeds. *Annu. Rev. Entomol.* **1998**, *43*, 369–393. [CrossRef]
2. Hoddle, M.S. Restoring balance: Using exotic species to control invasive exotic species. *Conserv. Biol.* **2004**, *18*, 38–49. [CrossRef]
3. Zimmermann, H.G.; Moran, V.C.; Hoffmann, J.H. Biological control in the management of invasive alien plants in South Africa, and the role of the Working for Water programme. *S. Afr. J. Sci.* **2004**, *100*, 34–40. Available online: https://hdl.handle.net/10520/EJC96216 (accessed on 11 November 2022).
4. Krug, R.M.; Richardson, D.M. Modelling the effect of two biocontrol agents on the invasive alien tree *Acacia cyclops*–Flowering, seed production and agent survival. *Ecol. Model.* **2014**, *278*, 100–113. [CrossRef]
5. Pemberton, R.W. Predictable risk to native plants in weed biological control. *Oecologia* **2000**, *125*, 489–494. [CrossRef] [PubMed]
6. van Klinken, R.D.; Edwards, O.R. Is host-specificity of weed biological control agents likely to evolve rapidly following establishment? *Ecol. Lett.* **2002**, *5*, 590–596. [CrossRef]
7. Messing, R.M.; Wright, M.G. Biological control of invasive species: Solution or pollution. *Front. Ecol. Environ.* **2006**, *4*, 132–140. [CrossRef]
8. Hinz, H.L.; Winston, R.L.; Schwarzländer, M. How safe is weed biological control? A global review of direct nontarget attack. *Q. Rev. Biol.* **2019**, *94*, 1–27. [CrossRef]
9. Veldtman, R.; Lado, T.F.; Botes, A.; Procheş, Ş.; Timm, A.E.; Geertsema, H.; Chown, S.L. Creating novel food webs on introduced Australian acacias: Indirect effects of galling biological control agents. *Divers. Distrib.* **2011**, *17*, 958–967. [CrossRef]
10. David, P.; Thebault, E.; Anneville, O.; Duyck, P.-F.; Chapuis, E.; Loeuille, N. Impacts of invasive species on food webs: A review of empirical data. *Adv. Ecol. Res.* **2017**, *56*, 1–60. [CrossRef]
11. Louda, S.M.; Kendall, D.; Connor, J.; Simberloff, D. Ecological effects of an insect introduced for the biological control of weeds. *Science* **1997**, *277*, 1088–1090. [CrossRef]
12. Carvalheiro, L.G.; Buckley, Y.M.; Ventim, R.; Fowler, S.V.; Memmott, J. Apparent competition can compromise the safety of highly specific biocontrol agents. *Ecol. Lett.* **2008**, *11*, 690–700. [CrossRef] [PubMed]
13. Ollivier, M.; Lesieur, V.; Raghu, S.; Martin, J.-F. Characterizing ecological interaction networks to support risk assessment in classical biological control of weeds. *Curr. Opinion Insect Sci.* **2020**, *38*, 40–47. [CrossRef]
14. Zachariades, C.; Paterson, I.D.; Strathie, L.W.; Hill, M.P.; van Wilgen, B.W. Assessing the status of biological control as a management tool for suppression of invasive alien plants in South Africa. *Bothalia* **2017**, *47*, a2142. [CrossRef]
15. Paterson, I.D.; Den Breeÿen, A.; Martin, G.D.; Olckers, T. An introduction to the fourth decadal review of biological control of invasive alien plants in South Africa (2011–2020). *Afr. Entomol.* **2021**, *29*, 685–692. [CrossRef]
16. McGeoch, M.A.; Chown, S.L. Evidence of competition in a herbivorous, gall-inhabiting moth (Lepidoptera) community. *Oikos* **1997**, *78*, 107–115. [CrossRef]
17. Bashford, R. The insect fauna inhabiting *Uromycladium* (Uredinales) rust galls on silver wattle (*Acacia dealbata*) in Tasmania. *Aust. Entomol.* **2002**, *29*, 81–95.
18. Crawford, K.M.; Crutsinger, G.M.; Sanders, N.J. Host-plant genotypic diversity mediates the distribution of an ecosystem engineer. *Ecology* **2007**, *88*, 2114–2120. [CrossRef]

19. Seymour, C.L.; Veldtman, R. Ecological role of control agent, and not just host-specificity, determine risks of biological control. *Austral Ecol.* **2010**, *35*, 704–711. [CrossRef]
20. Cornelissen, T.; Cintra, F.; Santos, J.C. Shelter-building insects and their role as ecosystem engineers. *Neotrop. Entomol.* **2016**, *45*, 1–12. [CrossRef]
21. Pearson, D.E.; Callaway, R.M. Indirect effects of host-specific biological control agents. *Trends Ecol. Evol.* **2003**, *18*, 456–461. [CrossRef]
22. Thomas, M.B.; Reid, A.M. Are exotic natural enemies an effective way of controlling invasive plants? *Trends Ecol. Evol.* **2007**, *22*, 447–453. [CrossRef] [PubMed]
23. López-Núñez, F.A.; Ribeiro, S.; Marchante, H.; Heleno, R.H.; Marchante, E. Life inside a gall: Diversity, phenology and structure of Portuguese gall communities, their hosts, parasitoids and inquilines. *Arthropod Plant Interact.* **2019**, *13*, 477–488. [CrossRef]
24. Le Maitre, D.C.; Gaertner, M.; Marchante, E.; Ens, E.-J.; Holmes, P.M.; Pauchard, A.; O'Farrell, P.J.; Rogers, A.M.; Blanchard, R.; Blignaut, J.; et al. Impacts of invasive Australian acacias: Implications for management and restoration. *Divers. Distrib.* **2011**, *17*, 1015–1029. [CrossRef]
25. Milton, S.J.; Hall, A.V. Reproductive biology of Australian acacias in the southwestern Cape Province, South Africa. *Trans. R. Soc. S. Afr.* **1981**, *44*, 465–487. [CrossRef]
26. Strydom, M.; Veldtman, R.; Ngwenya, M.Z.; Esler, K.J. Invasive Australian *Acacia* seed banks: Size and relationship with stem diameter in the presence of gall-forming biological control agents. *PLoS ONE* **2017**, *12*, e0181763. [CrossRef]
27. van Wilgen, B.W.; Dyer, C.; Hoffmann, J.H.; Ivey, P.; Le Maitre, D.C.; Moore, J.L.; Richardson, D.M.; Rouget, M.; Wannenburgh, A.; Wilson, J.R.U. National-scale strategic approaches for managing introduced plants: Insights from Australian acacias in South Africa. *Divers. Distrib.* **2011**, *17*, 1060–1075. [CrossRef]
28. Adair, R.J. The biology of *Dasineura dielsi* Rübsaamen (Diptera: Cecidomyiidae) in relation to the biological control of *Acacia cyclops* (Mimosaceae) in South Africa. *Aust. J. Entomol.* **2005**, *4*, 446–456. [CrossRef]
29. Post, J.A.; Kleinjan, C.A.; Hoffmann, J.H.; Impson, F.A.C. Biological control of *Acacia cyclops* in South Africa: The fundamental and realized host range of *Dasineura dielsi* (Diptera: Cecidomyiidae). *Biol. Control* **2010**, *53*, 68–75. [CrossRef]
30. Strydom, M.; Veldtman, R.; Ngwenya, M.Z.; Esler, K.J. Seed survival of Australian Acacia in the Western Cape of South Africa in the presence of biological control agents and given environmental variation. *PeerJ* **2019**, *7*, e6816. [CrossRef]
31. Impson, F.; Kleinjan, C.A.; Hoffman, J.H.; Post, J.A.; Wood, A.R. Biological control of Australian *Acacia* species and *Paraserianthes lophantha* (Willd.) Nielsen (Mimosaceae) in South Africa. *Afr. Entomol.* **2011**, *19*, 186–207. [CrossRef]
32. Blignaut, N.; Heyns, K.; Barnard, A. Monthly Report. Fransmanshoek Conservancy, Vleesbaai. 2017. Available online: http://boggomsbaai.co.za/Concervancy_Report_April_2017.pdf (accessed on 4 February 2021).
33. Mackintosh, T. Shelley Point News. Shelley Point Home Owners Association (SPHOA): St Helena Bay, South Africa, May 2019. Available online: www.SPHOA.co.za (accessed on 7 December 2022).
34. Mdlangu, T.L.H. The Influence of Mite Predation on the Efficacy of the Gall Midge, *Dasineura* sp., as a Biocontrol Agent of Australian Myrtle, *Leptospermum laevigatum* (Myrtaceae) in South Africa. Master's Dissertation, University of Fort Hare, Alice, South Africa, April 2010.
35. Impson, F.; Lyons, C. A re-assessment of mortality factors associated with the bud-galling midge, *Dasineura strobila*, a biological control agent of *Leptospermum laevigatum* in South Africa. *Afr. Entomol.* **2021**, *29*, 142–149. [CrossRef]
36. Lyons, C.; Impson, F.; Bam, S.; Mlokoti, T.; Hoffmann, J. Investigations into the efficacy of the biocontrol programme of Australian Myrtle, *Leptospermum laevigatum*, in South Africa: Lessons learnt and where to now? *Afr. Entomol.* **2021**, *29*, 784–790. [CrossRef]
37. Ramos, L.F.; Solar, R.R.C.; Santos, H.T.; Fagundes, M. Variation in community structure of gall-inducing insects associated with a tropical plant supports the hypothesis of competition in stressful habitats. *Ecol. Evol.* **2019**, *9*, 13919–13930. [CrossRef] [PubMed]
38. Kolesik, P.; Adair, R.J.; Eick, G. Nine new species of *Dasineura* (Diptera: Cecidomyiidae) from flowers of Australian *Acacia* (Mimosaceae). *Syst. Entomol.* **2005**, *30*, 454–479. [CrossRef]
39. Hidayat, P.; Arini; Guntoro, D.; Takasu, K.; Overholt, W.A. Biology and rearing of the cogongrass gall midge, *Orseolia javanica* Kieffer & Docters van Leeuwen-Reijnvaan (Diptera: Cecidomyiidae). *BioRxiv* **2020**, *28*, 1–21. [CrossRef]
40. Pratt, P.D.; Coombs, E.M.; Croft, B.A. Predation by phytoseiid mites on *Teranychus lintearius* (Acari: Tetranychidae), an established weed biological control agent of gorse (*Ulex europaeus*). *Biol. Control* **2003**, *26*, 40–47. [CrossRef]
41. Monfreda, R.; Lekveishvili, M.; Petanovic, R.; Amrine, J.W. Collection and detection of eriophyoid mites. In *Eriophyoid Mites: Progress and Prognoses*; Ueckermann, E.A., Ed.; Springer: Dordrecht, The Netherlands, 2009; pp. 273–282.
42. Ueckermann, E.A.; Grout, T.G. Tydeoid mites (Acari: Tydeidae, Edbakerellidae, Iolinidae) occurring on *Citrus* in southern Africa. *J. Nat. Hist.* **2007**, *41*, 2351–2378. [CrossRef]
43. Ueckermann, E.A.; Ochoa, R.; Bauchan, G.R.; Neser, S. An amazing sub-cambium flat mite from South Africa (Acari: Trombidiformes: Tenuipalpidae). *Acarologia* **2019**, *59*, 507–530. [CrossRef]
44. Krantz, G.W. *A Manual of Acarology*, 2nd ed.; Oregon State University (OSU) Bookstore: Corvallis, OR, USA, 1978; p. 509.
45. Broce, A.B.; Zurek, L.; Kalisch, J.A.; Brown, R.; Keith, D.L.; Gordon, D.; Goedeke, J.; Welbourn, C.; Moser, J.; Ochoa, R.; et al. *Pyemotes herfsi* (Acari: Pyemitidae), a mite new to North America as the cause of bite outbreaks. *J. Med. Entomol.* **2006**, *43*, 610–613. [CrossRef]

46. Stingeni, L.; Bianchi, L.; Hansel, K.; Neve, D.; Foti, C.; Corazza, M.; Bini, V.; Moretta, I.; Principato, M. Dermatitis caused by arthropods in domestic environment: An Italian multicentre study. *J. Eur. Dermatol. Venereol.* **2017**, *31*, 1526–1533. [CrossRef] [PubMed]
47. van der Walt, L.; Spotts, R.A.; Ueckermann, E.A.; Smit, F.J.; Jensen, T.; McLeod, A. The association of *Tarsonemus* mites (Acari: Heterostigmata) with different apple developmental stages and apple core rot diseases. *Int. J. Acarol.* **2011**, *37*, 71–84. [CrossRef]
48. Da Silva, G.L.; Da-Costa, T.; Ferraz, C.S.; Pallini, A.; Ferla, N.J. First description of iolinid mites (Acari: Tydeoidea) from Brazil. *Syst. Appl. Acarol.* **2017**, *22*, 694–701. [CrossRef]
49. Ueckermann, E.A. A revision of the family Adamystidae Cunliffe (Acari: Prostigmata). *Phytophlactica* **1989**, *21*, 227–240. Available online: https://hdl.handle.net/10520/AJA03701263_1258 (accessed on 11 November 2022).
50. Situngu, S.; Barker, N.P.; Vetter, S. A snap-shot of domatial mite diversity of *Coffea arabica* in comparison to the adjacent Umtamvuna Forest in South Africa. *Diversity* **2020**, *12*, 79. [CrossRef]
51. Fan, Q.-H.; George, S.; Kumarasinghe, L. Genus Acalvolia (Acari: Winterschmidtiidae), with the description of a new species from the USA. *Zootaxa* **2010**, *2719*, 41–61. [CrossRef]
52. Tixier, M.-S. Predatory mites (Acari: Phytoseiidae) in agro-ecosystems and conservation biological control: A review and explorative approach for forecasting plant-predatory mite interactions and mite dispersal. *Front. Ecol. Evol.* **2018**, *6*, 192. [CrossRef]
53. Norton, R.A.; Behan-Pelletier, V.M. Oribatida: Chapter 15. In *A Manual of Acarology*; Krantz, G.W., Walter, D.E., Eds.; Texas Tech University Press: Lubbock, TX, USA, 2009; pp. 430–564.
54. Walter, D.E.; Lindquist, E.E.; Smith, I.M.; Cook, D.R.; Krantz, G.W. Order Trombidiformes. In *A Manual of Acarology*; Krantz, G.W., Walter, D.E., Eds.; Texas Tech University Press: Lubbock, TX, USA, 2009; pp. 233–420.
55. Cross, E.A.; Moser, J.C.; Rack, G. Some new forms of *Pyemotes* (Acarina: Pyemotidae) from forest insects, with remarks on polymorphism. *Int. J. Acarol.* **1981**, *7*, 179–196. [CrossRef]
56. Scott, H.G.; Fine, R.M. Straw itch mite dermatitis caused by *Pyemotes ventricosus*. *Dermatol. Trop. Ecol. Geogr.* **1963**, *15*, 226–231. [CrossRef] [PubMed]
57. Kalisch, J.A.; Keith, D.L.; Broce, A.R. NF05-653 Pyemotes Itch Mites. Historical Materials from University of Nebraska-Lincoln Extension. 2005, p. 1737. Available online: https://digitalcommons.unl.edu/extensionhist/1737 (accessed on 24 February 2021).
58. O'Donel, A.J. Pyemotes Infestation. In *Arthropods and Human Skin*; Springer: London, UK, 1984. [CrossRef]
59. Heyne, H.; Ueckermann, E.A.; Coetzee, L. First report of a parasitic mite, *Leptotrombidium* (*Hypotrombidium*) *subquadratum* (Lawerence) (Acari: Trombiculidae: Trombiculinae), from dogs and children in the Bloemfontein area, South Africa. *J. S. Afr. Vet. Assoc.* **2001**, *72*, 105–106. [CrossRef]
60. Beck, W.; Fölster-Holst, R. Tropical rat mites (*Ornithonyssus bacoti*)—serious ectoparasites. *JDDG—J. German Soc. Dermatol.* **2009**, *7*, 667–670. [CrossRef] [PubMed]
61. Cafiero, M.A.; Raele, D.A.; Mancini, G.; Galante, D. Dermatitis by tropical rat mite, *Ornithonyssus bacoti* (Mesostigmata, Macronyssidae) in Italian city-dwellers: A diagnostic challenge. *J. Eur. Acad. Dermatol. Venereol.* **2016**, *30*, 1231–1233. [CrossRef] [PubMed]
62. Impson, F.; Kleinjan, C.A.; Hoffman, J.H.; Post, J.A. *Dasineura rubiformis* (Diptera: Cecidomyiidae), a new biological control agent for *Acacia mearnsii* in South Africa. *S. Afr. J. Sci.* **2008**, *104*, 247–249. Available online: https://hdl.handle.net/10520/EJC96827 (accessed on 11 November 2022).
63. Gordon, A.J. Biological control endeavours against Australian myrtle, *Leptospermum laevigatum* (Gaertn.) F.Muell. (Myrtaceae), in South Africa. *Afr. Entomol.* **2011**, *19*, 349–355. [CrossRef]
64. Pearson, D.E.; Clark, T.J.; Hahn, P.G. Evaluating unintended consequences of intentional species introductions and eradications for improved conservation management. *Conserv. Biol.* **2022**, *36*, e13734. [CrossRef]
65. Fowler, S.V.; Paynter, Q.; Dodd, S.; Groenteman, R. How can ecologists help practitioners minimize non-target effects in weed biocontrol? *J. Appl. Ecol.* **2012**, *49*, 307–310. [CrossRef]
66. Downey, P.O.; Paterson, I.D. Encompassing the relative non-target risks from agents and their alien plant targets in biological control assessments. *BioControl* **2016**, *61*, 615–630. [CrossRef]
67. Henriksen, M.V.; Chapple, D.G.; Chown, S.L.; McGeoch, M.A. Gall wasp biocontrol of invasive *Acacia longifolia*: Implications of strong bottom-up effects. *Ecosphere* **2017**, *8*, e02043. [CrossRef]
68. Barbosa, M.; Fernandes, G.W.; Morris, R.J. Interaction engineering: Non-trophic effects modify interactions in an insect galler community. *J. Anim. Ecol.* **2019**, *88*, 1168–1177. [CrossRef]

Disclaimer/Publisher's Note: The statements, opinions and data contained in all publications are solely those of the individual author(s) and contributor(s) and not of MDPI and/or the editor(s). MDPI and/or the editor(s) disclaim responsibility for any injury to people or property resulting from any ideas, methods, instructions or products referred to in the content.