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**The natural enemies of *Asparagus asparagoides* (L.) Wight in South Africa and their potential for use as biological control agents in Australia.**

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## The natural enemies of *Asparagus asparagoides* (L.) Wight in South Africa and their potential for use as biological control agents in Australia

### Abstract

A form of the southern African plant *Asparagus asparagoides* (Asparagaceae), is a serious environmental weed in Australia, where it is known as bridal creeper. Bridal creeper has an extensive underground tuber system and can invade native vegetation, two factors that make chemical and/or mechanical control difficult. The fruit is bird dispersed which facilitates colonisation of new sites. Surveys for potential biological control agents for use against bridal creeper in Australia were initiated in South Africa during 1989. This dissertation describes the identification, distribution and phenology of *A. asparagoides* in South Africa, as well as the natural enemies associated with the plant and their potential for use as biological control agents in Australia. Potential biological control agents that attack vegetative growth of bridal creeper included an undescribed *Zygina* sp. (Cicadellidae), two undescribed *Crioceris* species (Chrysomelidae - Criocerinae) and the rust fungus, *Puccinia myrsiphlli* DC. (Uredinales). The seeds of bridal creeper are attacked by an undescribed *Eurytoma* sp. (Eurytomidae) and the fruits by *Zalaca snelleni* (Wallengren) (Noctuidae). An organism directly attacking the tuber mass of bridal creeper was not found. Experimental results illustrated that herbivore damage to the above ground parts of the plant resulted in reduced tuber mass and also impacted negatively on fruit production.

## General Introduction

The family Asparagaceae is represented in Australia by 9 species (Clifford and Conran 1987), including commercial asparagus, *Asparagus officinalis* L. which originates from Europe (Valdes 1980). Only one species in Australia, *Asparagus racemosus* Willd., is considered to be indigenous. Its distribution extends from southern Africa through Africa and Asia to north-western Australia (Clifford and Conran 1987). The other 7 species originate from southern Africa and have become naturalised in Australia after having been introduced for horticultural purposes (Clifford and Conran 1987). Several of these species, including a form of *Asparagus asparagoides* known as bridal creeper in Australia, have raised concern due to their proliferation in natural ecosystems in Australia. Bridal creeper is also naturalised in New Zealand, South America and southern Europe (Robertson, 1983). It has been declared a Weed of National Significance in Australia (Wills, 1999).

Based on observations and the description of *A. asparagoides* by Obermeyer (1984, 1992), bridal creeper is a scandent, deciduous or semideciduous, perennial with twisting, wiry stems and shiny green, ovate phylloclades. The fruit is a globose, many seeded, red berry. Below ground bridal creeper is characterized by a tuber mass which consists of a branched, cylindrical rhizome bearing numerous fusiform root tubers.

Bridal creeper has various characteristics that make it a significant environmental weed. The branching rhizomes, bearing numerous tubers, entwine to form a dense mat just below the surface of the soil, in severe infestations this tuber mat may be almost continuous (Raymond, 1995). In addition, the stems creep over vegetation and grow into the canopies of trees and are capable of dominating the understorey (Raymond, 1995). The fact that the fruits are bird dispersed encourages colonisation of new sites. Bridal creeper is capable of invading both disturbed and undisturbed areas and can invade a large range of habitats (Humphries et al, 1991).

Bridal creeper has become widespread across southern Australia and has the potential to spread further both within and outside its current distribution (Scott and Kleinjan, 1991, Scott, 1995).

Established bridal creeper individuals have a large store of resources accumulated in their tuber mass which enable recovery from potential control methods. Slashing or burning of the foliage, or even the application of herbicides would require repetition in order to deplete these resources and kill the plants (Robertson, 1983, Pritchard, 1991). In addition, the application of herbicides may not be desirable as bare ground would be vulnerable to invasion by other exotics and the cost would be prohibitive over large areas (Humphries et al. 1991). The digging out of tuber masses may be feasible for new infestations but would be

unrealistic for established populations of bridal creeper (Robertson, 1983, Cooke and Robertson, 1990).

Bridal creeper was selected as a target for biological control and this dissertation documents the studies that were undertaken in South Africa, the plants native range, at the inception of the project.

A review of *A. asparagoides* and several related *Asparagus* species with broad cladodes had been undertaken by Obermeyer (1984). *Asparagus asparagoides* was documented as having an extensive distribution in southern Africa. Surveys of *A. asparagoides* and related *Asparagus* species were undertaken, from 1989 to 1993, throughout this documented range in South Africa. The findings of these surveys are detailed in Chapter 1, which describes the identification and distribution of two forms of *A. asparagoides* in South Africa, a widespread form known as bridal creeper in Australia and a south-western Cape form which does not occur in Australia.

The form of *Asparagus asparagoides* known as bridal creeper in Australia occurs under a variety of climatic conditions in South Africa and in winter, summer and a-seasonal rainfall regions. Chapter 2 describes the phenology of this form of *A. asparagoides* in these different regions.

The primary objective of this study was to identify organisms (insects or diseases) that may prove useful as biological control agents against bridal creeper in Australia. These are discussed in chapters 3 and 4.

Bridal creeper and its related *Asparagus* species, have extensive tuber reserves. The final chapter discusses the results of an experimental investigation into whether these tuber reserves can be reduced by the use of insects that damage above ground vegetative growth.

## Chapter 1

### The identification and distribution of *Asparagus asparagoides* in South Africa

#### Introduction

##### Taxonomy of genera within the Asparagaceae

The higher taxonomy of what is currently recognised as the family Asparagaceae has tended to oscillate between one and three genera. The genus *Asparagus* was originally described by Linnaeus (1753). It was divided for the first time with Willdenow's (1808) description of *Myrsiphyllum*. Roemer and Schultes (1829) then returned all species to the genus *Asparagus* L. Thereafter, Kunth (1850) recognised three genera (*Myrsiphyllum* Willd., *Asparagus* L. and *Asparagopsis* Kunth), but Baker (1875) returned all species to the genus *Asparagus* L.. Jessop (1966) revised the southern African *Asparagus* species and supported retention of a single genus within the Asparagaceae. Huber (1977) and Dahlgren and Clifford (1982) once again divided the genus into the three genera recognised by Kunth. (1850). Obermeyer (1983, 1984, 1985, 1992) revised the southern African species of Asparagaceae and also supported the recognition of three genera, replacing *Asparagopsis* Kunth, which is a later homonym of *Asparagopsis* Montagne (1840), by *Protasparagus*.

Malcomber and Sebsebe (1993) showed that of the criteria used by Obermeyer to separate *Asparagus* and *Protasparagus*, only the presence of monoecious versus dioecious flowers was consistent, however they did not support recognising two distinct genera on the basis of this characteristic. They also showed that, with the exception of the presence of connivent filaments, the genus *Myrsiphyllum* was not consistently different from the other two genera. They retained *Myrsiphyllum* as a subgenus of *Asparagus*. Fellingham and Meyer (1995) did not consider connivent filaments to be a useful characteristic, and concluded that the separation of *Asparagus* into subgenera was not warranted.

##### Taxonomic status and identity of *Asparagus asparagoides*

On the basis of cladode morphology, Jessop (1966) was unable to identify discontinuities between several *Asparagus* species with broad cladodes (*A. asparagoides*, *A. ovatus* T.M. Salter, *A. kraussianus* (Kunth) J.F. Macbr., *A. multituberosus* R.A. Dyer, *A. volubilis* Thunb. and *A. undulatus* (L. f.) Thunb.), and incorporated all, except *A. undulatus*, into *A. asparagoides*. He noted that *A. asparagoides* sensu Salter and *A. kraussianus* sensu Salter grow sympatrically and that consequently a genetic basis for the differences must occur, but even so did not recognise them as distinct species. Obermeyer (1984) placed considerable emphasis on features of the tuber system to distinguish *Myrsiphyllum* (sensu Obermeyer)

species, and re-divided *A. asparagoides* sensu Jessop into five species (*M. asparagoides*, *M. ovatum*, *M. kraussianum*, *M. multituberosum* and *M. volubile*).

In the absence of tuber material, *A. asparagoides* (sensu Obermeyer) is easily confused with other species, most notably *A. multituberosus* and *A. ovatus*. Under certain circumstances, it is also readily confused with *A. kraussianus* from which it can be distinguished on the basis of above ground morphology but not the tuber system.

During surveys on the distribution of *A. asparagoides* (sensu Obermeyer) in South Africa, it became apparent that there are two distinct forms of the plant, a south-western Cape form and a widespread form. A description of the differences between the two forms was compiled based on several parameters that were measured to quantify the differences between the two forms. The description shows that it is the widespread form of *A. asparagoides* that occurs in Australia and it is this form that is referred to when the name 'bridal creeper' is used in the text that follows.

## Methods

We examined *Asparagus asparagoides* material from the Compton Herbarium at the Kirstenbosch Botanical Gardens, the Bolus Herbarium at the University of Cape Town and the National Herbarium in Pretoria. A record was kept of specimens which could be positively identified as *A. asparagoides* (sensu Obermeyer), this required that tuber material was present. A large number of specimens identified as *A. asparagoides* did not have tuber material. A record was kept of these specimens as well to enable further searches to be concentrated at the localities from which they originated. Surveys for *A. asparagoides* were carried out throughout the South African range documented by Obermeyer (1984). Due to the growth habit of *Asparagus asparagoides*, and the other broad-cladode *Asparagus* species, of climbing within shrubs and bushes, searches were conducted on foot, often crawling through undergrowth. Searches were usually conducted in micro-habitats favoured by broad cladode *Asparagus* species. Records were kept of the habitat associations of *A. asparagoides*.

## Results

### Identification of *A. asparagoides*

The two forms of *A. asparagoides* can be distinguished as follows.

**widespread form of *A. asparagoides*:** Rhizome usually slender (diameter:  $5.4 \pm 1.7$  mm (S.D.) (n=216 rhizomes from 216 plants from 62 localities distributed throughout the plant's South African range)). Direction of rhizome growth parallel to the soil surface, frequent

branching. **Tubers** length  $25.4 \pm 6.0$  mm (S.D.) up to 42 mm (n=264 tubers from 264 plants from 62 localities), fusiform, not all continue as roots, arranged spirally on the rhizome. The density of packing of tubers is highly variable. Large plants have an extensive, much-branched mat of tubers at their base.

**South-western Cape form of *A. asparagoides*:** **Rhizome** robust (diameter  $8.1 \pm 2.8$  mm (S.D.) (n=17 rhizomes from 17 plants from 10 localities)). Direction of rhizome growth primarily upwards towards soil surface. **Tubers** length  $43.2 \pm 13.6$  mm (S.D.) up to 73 mm (n=19 tubers from 19 plants from 10 localities), fusiform, slightly curved, usually longitudinally wrinkled. All tubers continue as fine roots. Tubers lie parallel to the ground and are closely packed in a rosette round the rhizome such that large individuals have a compact cluster of tubers at their base.

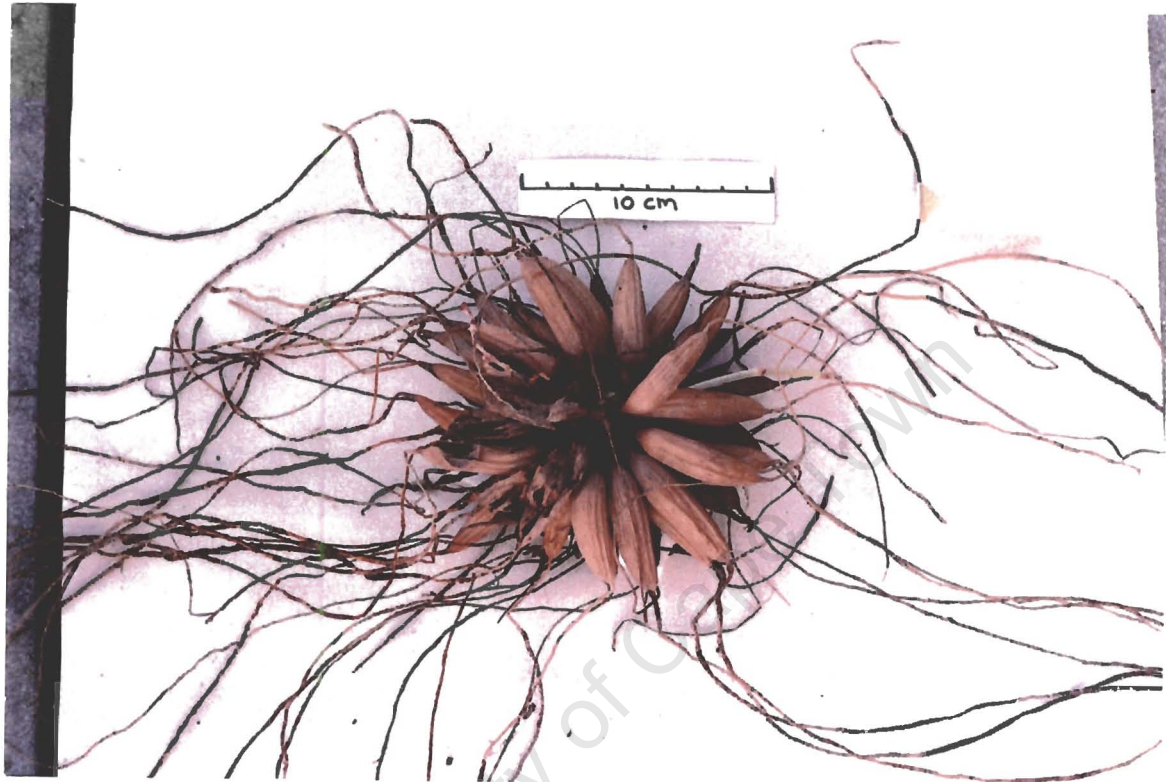
The tuber length of bridal creeper plants from Australia was  $22.5 \pm 2.6$  mm (S.D) (n=5, 1 tuber from 5 localities), which is consistent with tuber measurements from the 'widespread' form of *A. asparagoides* in southern Africa. An illustration of Australian bridal creeper is given in Fig. 1.1c.

While the widespread and south-western Cape forms can be readily separated on the basis of tuber morphology (Fig. 1.1a and b), they cannot always be separated on the basis of above-ground growth. Nonetheless the cladodes of the south-western Cape form of *A. asparagoides* are inclined to be dull green in colour and more leathery in texture enabling reasonably accurate field identification for those familiar with both forms of the plant. The cladodes of bridal creeper are usually glossy and grass-green in colour but when growing in sunny positions may be dull, light green and leathery. Apart from the fact that considerable variation exists, the colour of cladodes is not maintained in herbarium specimens and consequently this character is not useful for identification of herbarium specimens.

Similarly, cladode size is not a reliable criterion for separation of the two forms of *A. asparagoides*. One fully expanded cladode was selected at random per plant, to provide comparative statistics on cladode size (Table 1.1). The measurements for the south-western Cape form of *A. asparagoides* are similar to those of the widespread form of *A. asparagoides* from the winter rainfall region. (See below for definition of rainfall zones).

Seedlings and young individuals of these two forms cannot be readily distinguished by either below or above ground characteristics.

**Fig 1.1:** The tuber mass of (a) the South-western Cape form of *Asparagus asparagoides* and (b) the widespread form of *A. Asparagoides* illustrating the presence of a compact cluster of tubers at the base of the Western- Cape form of the plant in contrast to the much branched mat of smaller tubers present in the widespread form. Also shown overleaf is (c) the form of the plant present in Australia (bridal creeper) illustrating that the morphology of the tubers most closely resembles the widespread form of *A. asparagoides* in southern Africa.



(a)



(b)

**Fig 1.1(cont.):** The tuber mass (c) of the form of the plant present in Australia (bridal creeper) illustrating that the morphology of the tubers is like that of the widespread form of *A. asparagoides* in southern Africa.



(c)

Table 1.1: Cladode dimensions of **a)** the 'widespread' form of *A. asparagoides* (bridal creeper) in the three rainfall regions of South Africa, as well as in Australia and **b)** of the 'South-western Cape' form of *A. asparagoides* which is restricted to the winter rainfall region of South Africa.

**a) 'widespread' form of *A. asparagoides***

	<u>cladode length (mm)</u>	<u>cladode width (mm)</u>
summer rainfall region (n=34 plants from 23 localities)	21.7 ± 4.2 (S.D)	8.9 ± 2.7 (S.D)
a-seasonal rainfall region (n=46 plants from 17 localities)	28.2 ± 9.0 (S.D)	10.9 ± 2.7 (S.D)
winter rainfall region (n=42 plants from 15 localities)	36.2 ± 8.2 (S.D)	15.5 ± 3.5 (S.D)
Australia (n=5 plants from 5 localities)	28.2 ± 5.4 (S.D)	11.4 ± 3.3 (S.D)

**b) 'South-western Cape' form of *A. asparagoides***

winter rainfall region (n=12 plants from 10 localities)	37.3 ± 6.2 (S.D)	14.8 ± 2.8 (S.D)
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## Distribution

The distribution of *A. asparagoides* is shown in Fig. 1.2a, it includes separation of *A. asparagoides* into the widespread form and the south-western Cape form. Localities mentioned in the text are included in Fig 1.2b, and details of all localities plotted on Fig. 1.2a are listed in Appendix 1. Appendix 1 indicates whether voucher specimens were made of the records, and where these are located.

Surveys were not carried out in a quantifiable manner, due to the growth habit of *A. asparagoides* and other broad-cladode *Asparagus* species of growing within shrubs and bushes, and also because of the large area being surveyed. Records were kept of all *Asparagus* (previously *Myrsiphyllum*) species, encountered during the surveys. These are listed in Appendix 2. The quarter degree square grid references are mapped in Fig. 1.3 to provide an indication of the intensity of the search for *A. asparagoides* within its previously documented range (Obermeyer 1984).

Rainfall regions of South Africa have been indicated on Fig. 1.2, based on the percentage of the annual rainfall that falls in the three summer months, December to February (data from Anon (1954)). If less than 20% falls in these months, the climate is described as "winter rainfall". If 20 - 30% falls in these months the climate is "a-seasonal rainfall", and if over 30% the climate is "summer rainfall". This delimitation provided a better reflection of the response of bridal creeper to rainfall patterns than did the more usual description of rainfall zones based on the totals falling in the six months October to March.

*Summer rainfall region.* In the summer-rainfall region of southern Africa, bridal creeper appears to be restricted to high altitudes (above approximately 550 m) and it is abundant in the Drakensberg mountain range. NBI (Pretoria) herbarium specimens labelled *M. asparagoides* from the subtropical coast of Kwazulu-Natal did not have tuber material, but had large, strongly veined cladodes, quite unlike those of *A. asparagoides* (see Table 1.2). For some reason not all NBI (Pretoria) specimens from South Africa labelled as *M. (=A.) asparagoides* were included in the map provided by Obermeyer (1984) (reproduced in Fig. 1.4a). Intensive searching on the subtropical coast of Kwazulu-Natal revealed only *A. ovatus*, and we suspect that the herbarium specimens labelled *M. asparagoides* from this area are in fact *A. ovatus*. In addition, NBI (Pretoria) herbarium specimens of *A. asparagoides* from tropical Africa also have large strongly veined cladodes (listed in Table 1.2), and in the one specimen where tuber material was included the tubers were on thread-like roots, and this specimen should have been identified as *M. ovatum* (now *A. ovatus*). The identity of the other specimens cannot be ascertained: We do not exclude the possibility that the distribution of *A. asparagoides* extends northwards beyond the borders of southern Africa, at high altitudes, but this still requires confirmation by collection of specimens with tubers.

Fig 1.2: (a) Revised distribution of *Asparagus asparagoides*, depicting the widespread form (bridal creeper) and the south-western Cape form. Rainfall regions defined as: WR = winter rainfall, < 20% of annual rainfall falls in December to February inclusive, AR = a-seasonal rainfall, 20% - 30% of annual rainfall falls in December to February inclusive, SR = summer-rainfall, > 30% of annual rainfall falls in December to February inclusive. (b) Localities mentioned in the text.

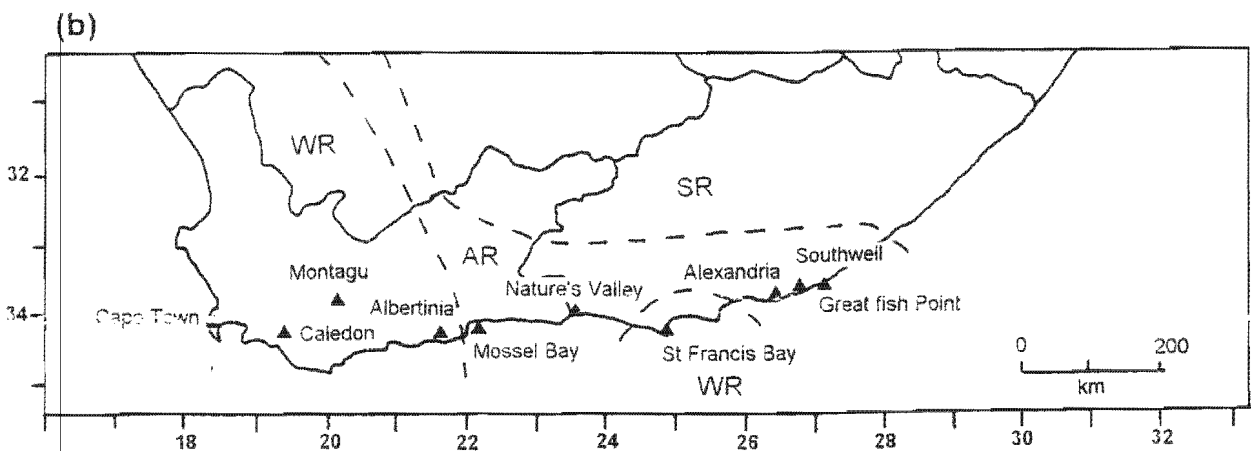
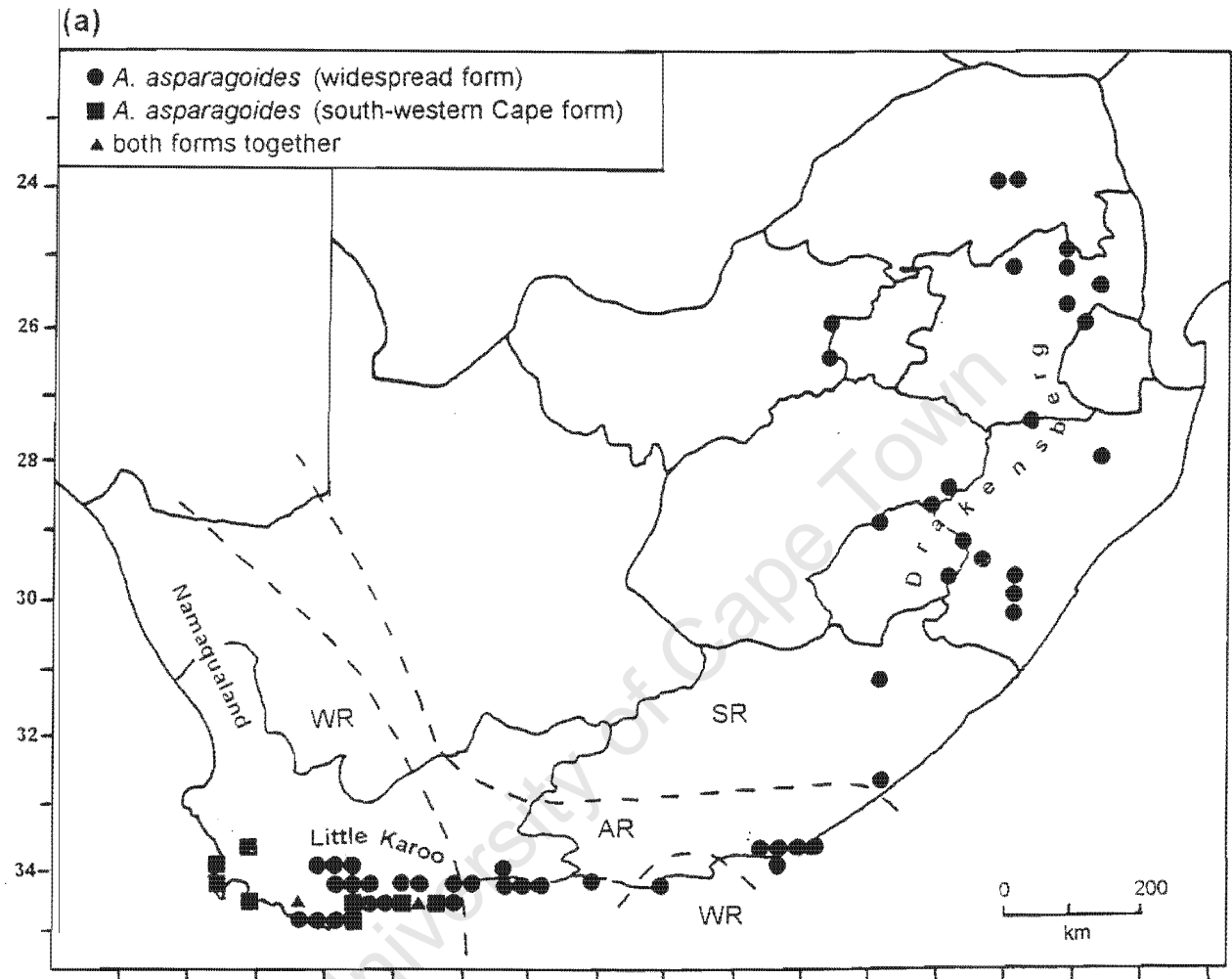


Fig 1.3: All records of *Asparagus* (previously *Myrsiphyllum*) species recorded during the CSIRO survey in South Africa and plotted as quarter degree squares. Locality details are listed in Appendix 2.

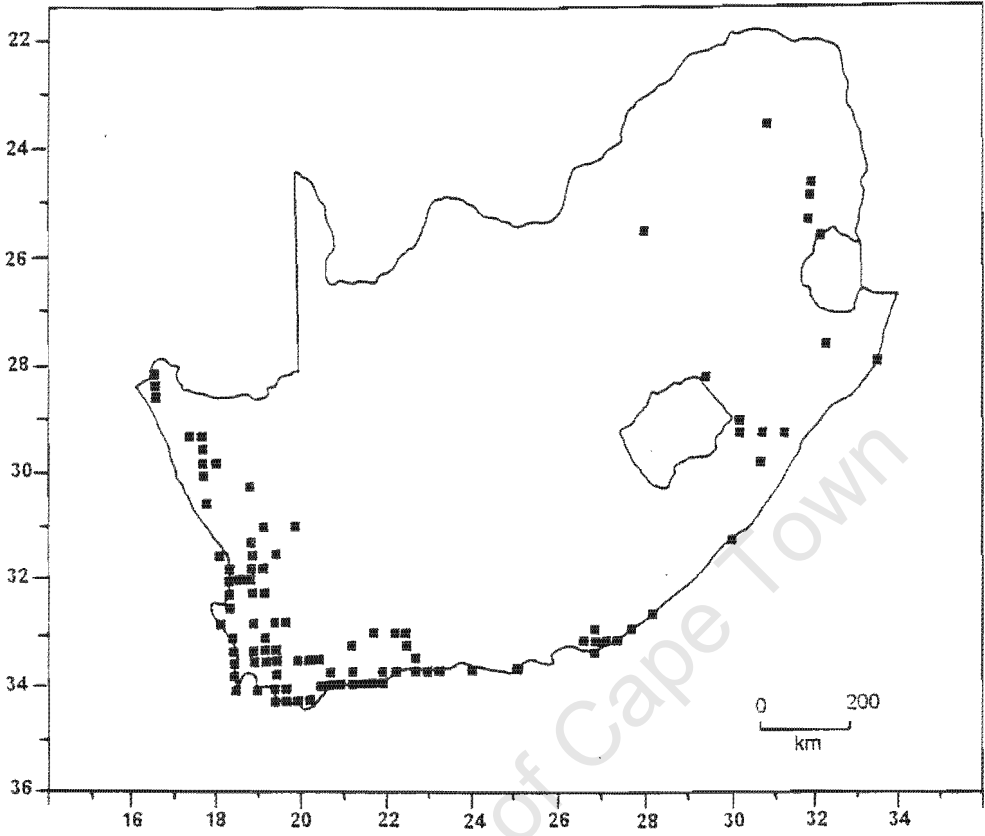


Table 1.2. Specimens in the National Herbarium, Pretoria labelled as *Myrsiphyllum* (= *Asparagus*) *asparagoides*, which have large, strongly veined cladodes, and no tubers (apart from the specimen from Kigezi District)

Herbarium record	Region	Date
Hoey's Bridge, Nzoia area	Kenya	1963.08.15
Teita Hills, Ngangoa Mountain	Kenya	1966.02.09
Thika near Chenia Falls	Kenya	1951.02.18
Sikwajo, Ngoye Forest, Mtunzini District	Kwazulu-Natal (RSA)	1965.09.14
Bangazi Lake, Hlabisi District	Kwazulu-Natal (RSA)	1964.06.20
Parc des Volcans, base of Mt. Visoke	Rwanda	1975.01.31
Kigezi District, Virunga-Ostgruppe <sup>1</sup>	Uganda	1954.10.27
Bergbambaswoold, Kivu South, Kahuzi	Zaire	1955.01.25
Kabindi	Zaire	1932
Mt. Biega, Kivu	Zaire	1972.01.06

<sup>1</sup> The specimen from "Kigezi District, Virunga-Ostgruppe" has tubers on stalks and should therefore have been identified as *A. ovatus*.

*A-seasonal rainfall region.* Bridal creeper is common in the coastal zone of the a-seasonal rainfall region of the Western Cape, between Mossel Bay and the border with the Eastern Cape, and from Alexandria to Great Fish Point and inland to Southwell in the a-seasonal-rainfall region of the Eastern Cape (Fig 1.2).

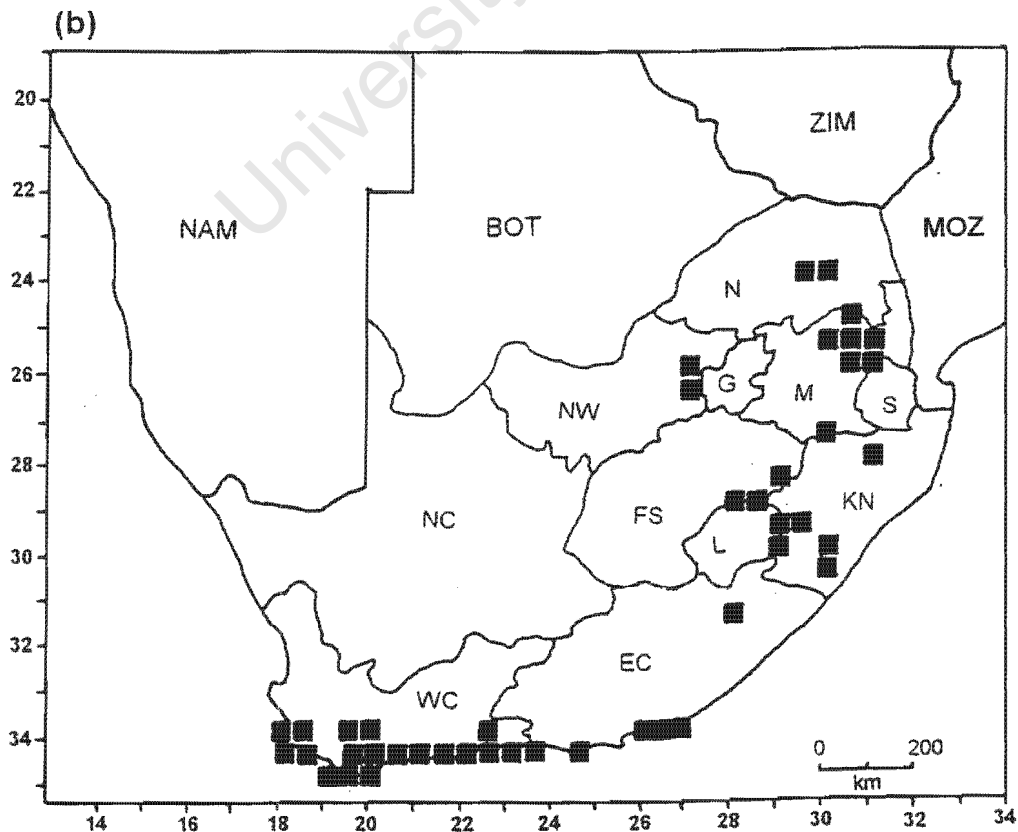
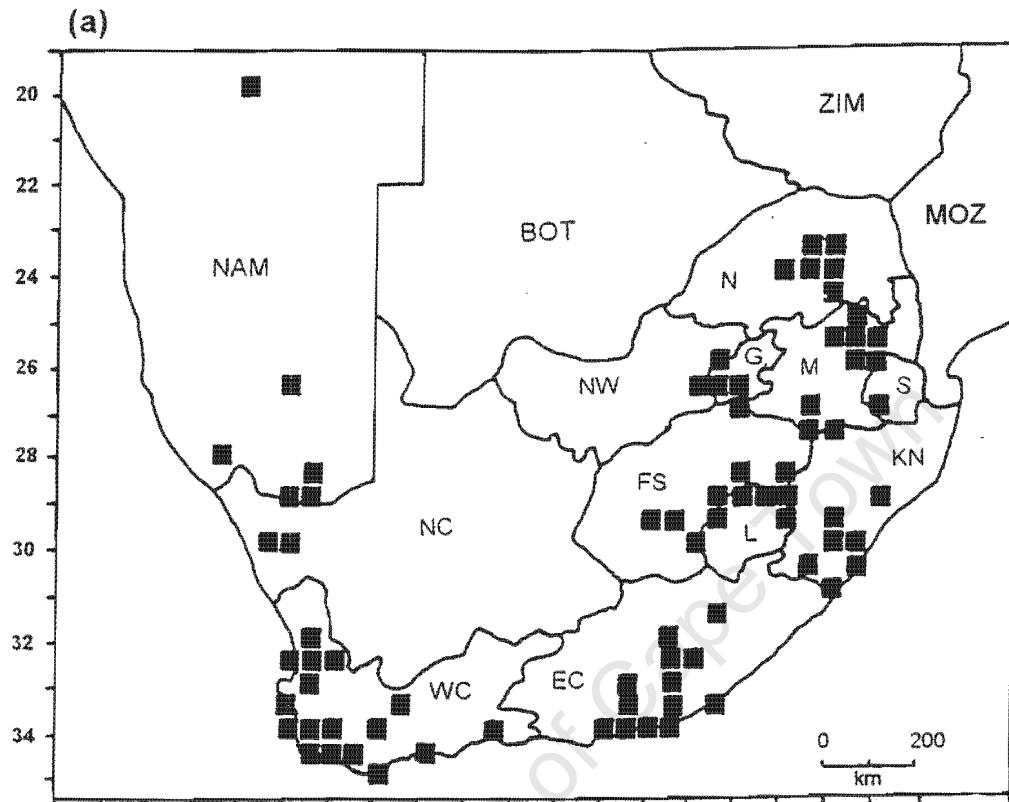
*Winter rainfall region.* The only area within the winter rainfall region of the Western Cape where bridal creeper occurs is the region bounded by Caledon in the west, Albertinia in the east and Montagu in the north (Fig.1.2). The south-western Cape form of *A. asparagoides* also occurs in this region but the two species have not been found growing together although they have been found within the same quarter degree square (Fig 1.2). Several of the localities of NBI (Pretoria) herbarium specimens labelled as *M.(=A.) asparagoides* but without tubers, from the more arid interior of the Western Cape (Little Karoo), have not been verified. Searching in this area only revealed an arid form of *A. ovatus*, and we suspect that the specimens in the NBI (Pretoria) herbarium represent this species. Bridal creeper was also recorded in the winter rainfall region of the Eastern Cape at St Francis Bay.

Bridal creeper does not occur on the mountain slopes around Cape Town or in the immediate interior, whereas the south-western Cape form of *A. asparagoides* is common in this region (Fig1.2).

The winter-rainfall arid west coast region of South Africa (Namaqualand) contains a wealth of *Asparagus* (previously *Myrsiphyllum*) species with broad cladodes, several of which are indistinguishable from bridal creeper when tuber material is unavailable. In addition, young specimens of *A. kraussianus* that have been growing in shady situations, may be confused with bridal creeper, even if tuber material is present. Although these two species are not readily separable from characteristics of the tuber system, the cladode characteristics and floral structures are distinct. The pedicel length in *A. asparagoides* is approximately 10mm, whereas that of *A. kraussianus* is approximately 3-5mm (Obermeyer 1984). In addition, the two species respond differently when growing in exposed situations, where bridal creeper has a stunted appearance with small compact ovate cladodes, and *A. kraussianus* develops ribbon-like cladodes with a distinct mid-vein. Extensive searching did not reveal any specimens of *A. asparagoides* in the Namaqualand area, although several other *Asparagus* species with broad cladodes were commonly encountered, including *A. kraussianus*. Appendix 2 lists all *Asparagus* (previously *Myrsiphyllum*) species that were encountered.

As outlined above, the distribution of *A. asparagoides*, differs considerably from that documented in Obermeyer(1984). These differences are summarised in Fig. 1.4 which presents a) the distribution provided in Obermeyer (1984) and b) the revised distribution for *A. asparagoides* based on the surveys undertaken during this study.

Fig 1.4: (a) Previously published distribution of *Asparagus asparagoides* (Obermeyer 1984, 1992) plotted as half degree map references. (b) Revised distribution map of *A. asparagoides*, based on current survey plus herbarium records validated by the presence of tubers (see text for details) plotted as half degree map references. (WC = Western Cape, NC = Northern Cape, EC = Eastern Cape, FS = Free State, NW = Northwest, N = Northern Province, G = Gauteng, M = Mpumalanga, KN = Kwazulu-Natal, L = Lesotho, S = Swaziland, NAM = Namibia, BOT = Botswana, ZIM = Zimbabwe, MOZ = Mozambique)



## **Habitat associations of the widespread form of *A. asparagoides* (bridal creeper) in South Africa**

Throughout its range bridal creeper occurs primarily in dappled shade or at the edges of dense shade. It is usually found scrambling within shrubs, on the lower branches of trees, on fences and occasionally in tall grass. In shady situations, in the absence of support, long prostrate stems are produced which produce little or no fruit. When growing in exposed sunny positions, bridal creeper produces many short stems with small, firm cladodes and has a compact appearance. Plants are usually found on relatively soft substrates, varying from almost pure sand to rich humus. However, they also occur on exposed rocks with the roots extending through cracks to the soil surface, and in clay soil, with no noticeable variation in the structure of the tuber mass.

Within the summer rainfall region of southern Africa, bridal creeper is particularly abundant along the Drakensberg escarpment in Kwazulu Natal, Mpumalanga and Northern Province. It was recorded at the edges of dense forest patches, amongst vegetation in gorges, under isolated bushes and on vegetated cliff faces and rocky outcrops. It was also recorded at the edge of a pine plantation and in roadside scrub.

In the Eastern Cape, which includes winter, a-seasonal and summer rainfall regions, bridal creeper occurs primarily amongst mesic vegetation. It was recorded at forest edges and within patches of shrubs and trees in grassland, particularly among rocky outcrops. It also occurs in coastal and roadside scrub.

In the a-seasonal rainfall region of the Western Cape (Mossel Bay to Natures Valley) bridal creeper occurs at forest edges, particularly in the coastal belt, and along the banks of estuaries. It also occurs amongst shrubs in grassland or "fynbos" and in stands of alien *Acacia* species. In the winter rainfall region of the Western Cape bridal creeper was recorded amongst shrubs on the slopes of mountains, in gorges at the base of mountains, in patches of dense vegetation along streams and in roadside scrub and alien *Acacia* thickets. As in the Eastern Cape, it was mainly found in mesic micro-habitats.

## **Discussion**

### **Identification of *A. asparagoides* and of the plant known in Australia as bridal creeper**

Part of the confusion surrounding the source of Australian bridal creeper arises from authors differing in their delimitation of species within *Asparagus* (particularly those species with broad cladodes which were formerly in *Myrsiphyllum*). Obermeyer (1984, 1992) relied on tuber

morphology to identify broad-cladode *Asparagus* species. The results of the current surveys also indicated that tuber morphology was essential for distinguishing several of the broad-cladode *Asparagus* species from each other, most notably, *A. asparagoides*, *A. ovatus* and *A. multituberosus*.

The survey results do not support Jessop's (1966) contention that the structure of the tuber mass is controlled by the substrate and that *A. ovatus*, *A. multituberosus*, *A. asparagoides*, *A. volubilis* and *A. kraussianus* are variants of a single species, *A. asparagoides*. For instance, *A. ovatus* and *A. asparagoides* were found growing within a metre of each other at the mouth of the Fish River (Eastern Cape), where they were easily separated on the basis of tuber morphology. The results of this survey have revealed that tuber morphology of *A. asparagoides* is constant with respect to the distance of the tubers from the rhizome, and that this is largely independent of the substrate. However tuber morphology differs in several respects, namely size, density and arrangement on the rhizome. Jessop (1966) also noted that *A. kraussianus* and *A. asparagoides* grow sympatrically, but chose to retain them as a single species. These species were also found growing sympatrically during this survey supporting Obermeyer's (1984) taxonomic separation of them. As outlined in the results section, these two species are not readily identifiable from the tuber system, but the cladode characteristics and floral structures are distinct. In addition, the two species respond differently when growing in an exposed situation.

The results of this survey largely supported the *Asparagus*, (previously *Myrsiphyllum*) species, recognised by Obermeyer (1984, 1992). However, two forms of *A. asparagoides* (sensu Obermeyer) were recognised, a widespread form and a south-western Cape form. Further analysis may indicate that these two forms warrant separation at the species level. Accurate identification of the form occurring in Australia is essential as the search for potential biological control agents for use in Australia must concentrate on the form occurring in Australia and further, because the two forms occur within different regions of South Africa and this has implications for the potential spread of bridal creeper within Australia.

Cooke and Robertson (1990) stated that bridal creeper in Australia is less variable than that occurring in South Africa, and suggest that this implies introduction from a restricted area of the plant's native distribution. It appears that this statement is based on Jessop's (1966) description of *A. asparagoides* as no reference is made to Obermeyer's (1984) revision. Their assertion that the form in Australia matches that occurring on the mountain slopes around Cape Town is based on the fact that the tubers are close to the rhizome. However, *A. asparagoides* is widespread in South Africa, and it is not clear why they singled out the Cape Town region, since tubers are close to the rhizome throughout the South African range of *A. asparagoides* (sensu Obermeyer). Jessop (1966) maintained that a 'variant' of bridal creeper (i.e. *A. asparagoides*) with tubers remote from the rhizome occurs on dunes in South Africa.

However this is almost certainly the taxon recognised by Obermeyer (1984, 1992) as *A. ovatus*. As stated above, the tuber morphology of *A. asparagoides* (sensu Obermeyer) was found to be constant, regardless of substrate during this survey. The evidence from Australia also supports this, since the tubers of *A. asparagoides* are close to the rhizome, no matter what substrate the plant is growing in (Cooke and Robertson 1990).

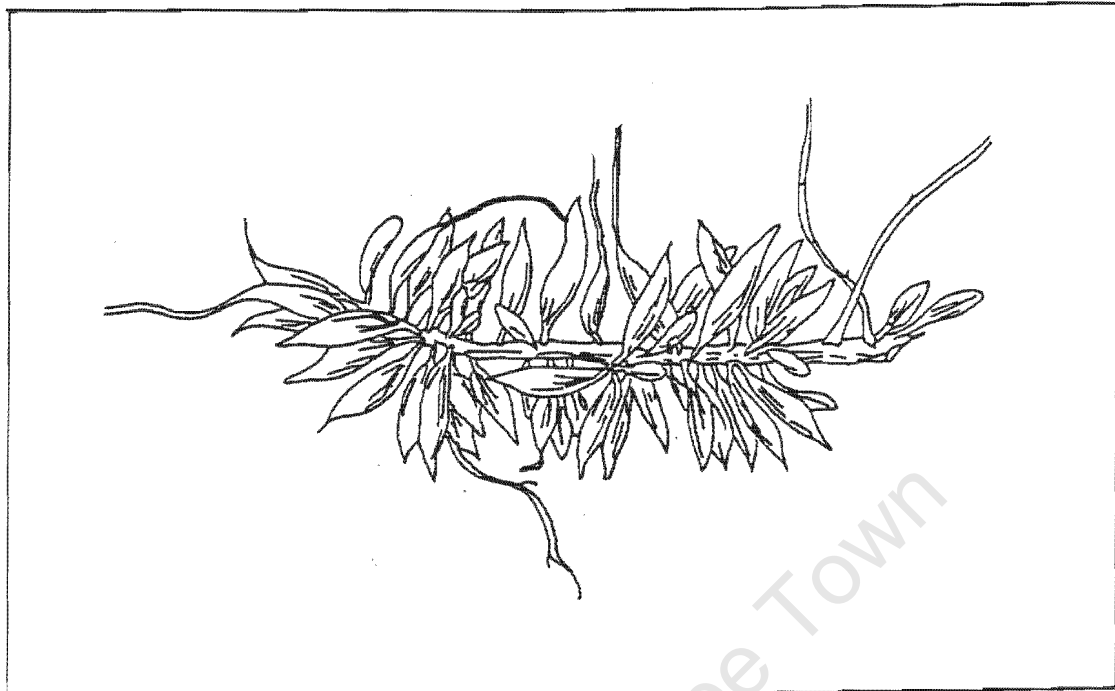
Comparisons of specimens of bridal creeper from Australia with material from southern Africa indicated that the Australian taxon is the same as the widespread southern African form of *A. asparagoides*. It also became apparent that the Cape Town region could not have been the source of bridal creeper in Australia, as suggested by Cooke and Robertson (1990), because the widespread form of *A. asparagoides* was never found in the Cape Town region despite intensive searching. The south-western Cape form of *A. asparagoides* is common in this region.

It is interesting to note that the description of *A. asparagoides* is based on an iconotype which does not have a precise collection locality. Although this figure from Tilli's catalogue (1723) is regarded as the type specimen for *A. asparagoides*, it is inadequate for determining which taxon is being represented. Although tubers are illustrated, the two plants depicted in the drawing do not possess rhizomes and are therefore probably young plants. It is virtually impossible to distinguish between young plants of the two forms of *A. asparagoides* or, under certain circumstances, *A. kraussianus* even if tubers are present. Obermeyer (1984) notes that previous authors have regarded the right hand figure as representing *A. kraussianus*, but she suggests that the variation between the cladodes in the two illustrations is within the range of *A. asparagoides*. The general appearance of the cladodes on the left hand illustration, based on our experience, suggests it is more likely to be the south-western Cape form of *A. asparagoides*. In contrast, the drawing of the tubers of *A. asparagoides* given by Obermeyer (1984), clearly indicates that she has based her description of the widespread form of *A. asparagoides* (Fig. 1.5).

#### **Distribution of *A. asparagoides* in South Africa**

In spite of the fact that Obermeyer (1984, 1992) relied on tuber morphology for identification of broad-cladode *Asparagus* species, 86 % of the 176 specimens labelled as *M.(=A) asparagoides* in the herbarium at the National Botanical Institute (NBI) in Pretoria, do not include tuber material. These identifications are therefore unreliable, but were used by Obermeyer (1984) to document the range of *A. asparagoides* in southern Africa (Fig. 1.4a). Furthermore there are inconsistencies between locality data on the specimens at the NBI (Pretoria) and the map provided by Obermeyer (1984), further compromising the reliability of her map.

Fig 1.5: Illustration of the tuber mass of *Asparagus asparagoides* given in Obermeyer (1984) which demonstrates that she based her description of this species on the "widespread form" of the plant.



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The revised distribution map of *A. asparagoides*, showing the distribution of both forms of the plant, excludes the dry interior of the Western Cape and Northern Cape, and the hot subtropical coast of Kwazulu-Natal. This has implications for predicting the potential range of bridal creeper in Australia (e.g. Scott, 1996). Nonetheless, bridal creeper has a wide distribution in southern Africa, including regions within the three main rainfall patterns. Much of the Australian distribution of bridal creeper occurs in winter -rainfall regions, and it is essential that biological control agents that are selected for bridal creeper infestations in winter rainfall areas of Australia are able to survive the summer months when bridal creeper senescens. For this reason the search for potential agents has concentrated on bridal creeper within the winter-rainfall region of the Western Cape.

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## Chapter 2

### Phenology of bridal creeper (widespread form of *Asparagus asparagoides*) in South Africa

#### Introduction

Bridal creeper, the widespread form of *A. asparagoides* is widespread in South Africa and it occurs in all three rainfall regions. The phenology of bridal creeper may vary with climate type. This in turn may impact significantly on the insects and diseases associated with bridal creeper in the various rainfall regions with implications for the type of organisms selected as potential biological control agents against bridal creeper in Australia. The phenology of bridal creeper in the three rainfall regions is investigated below.

#### Methods

Monitoring sites were selected throughout the South African range of bridal creeper so as to include sites within each of the three rainfall zones (delineated as described in Chapter 1). The intervals at which sites within the three rainfall zones were visited and the method used to establish the sites varied and each is treated separately.

##### **A-seasonal rainfall region:**

Sites were established in the a-seasonal-rainfall region of the Western Cape (Mossel Bay to the Eastern Cape border) during November 1990. The primary selection criterion was the presence of a relatively high density of bridal creeper. The following site localities were established:

- 1) Brenton Lake (34<sup>0</sup>04'S 23<sup>0</sup>02'E) in coastal forest artificially cleared of undergrowth
- 2) Kaaimans River Mouth (34<sup>0</sup>00'S 22<sup>0</sup>33'E) on the edge of coastal forest
- 3) Lake Pleasant (34<sup>0</sup>02'S 22<sup>0</sup>50'E) in coastal scrub/ alien *Acacia* thickets
- 4) Phantom Pass (34<sup>0</sup>01'S 23<sup>0</sup>00'E) on the edge of estuarine forest
- 5) Sedgfield (34<sup>0</sup>02'S 22<sup>0</sup>48'E) in coastal scrub/ alien *Acacia* thickets

Twenty plants were randomly selected from 100 sampled at Kaaimans River Mouth, Brenton Lake and Lake Pleasant. The density of bridal creeper plants was lower at the other two localities so 20 plants were randomly selected from 60 plants. The randomisation method was as follows: 20 numbered cards between 1 and 100 (or between 1 and 60, when bridal creeper density at the site appeared lower) were extracted from a container by an assistant, bridal creeper plants along a transect were counted and when the plant number matched a selected card number, it was allocated to be included in the monitoring schedule. To ensure that the counting of plants along the transect was unbiased, the numbers extracted from the

container were not known to the person counting the plants. For the purposes of the monitoring programme a "plant" was defined as a cluster of stems emerging from the same area of the ground. A numbered stake was placed in the ground adjacent to the plant and the stems were tagged near the base. The sites in the a-seasonal rainfall region were visited at quarterly intervals (November, February, May and August) from November 1990 to November 1992.

The following parameters were recorded:

- number of new shoots emerging from the tuber mass
- presence/absence of senescence
- presence/absence of active growth
- estimate of amount of flower buds
- estimate of amount of flowers
- estimate of amount of green fruit
- estimate of amount of ripe fruit

(the amount of buds, flowers, green fruit and ripe fruit was estimated and allocated a code ranging between 0=none and 9=profuse). An indication of the size of the plants being monitored was recorded by noting the number of stems and the approximate length of the longest stem of each plant.

Bridal creeper was also monitored, in the a-seasonal rainfall region of the Eastern Cape. The parameters listed above were recorded for the first 20 plants located at each of the following localities. The dates that monitoring took place are listed.

- 1) Moneyworth farm (33°38'S 26°40'E) - November 1992
- 2) Cannon rocks (33°45'S 26°31'E) - November 1992
- 3) Alexandria Forest (33°42'S 26°22'E) - November 1992
- 4) Fish River Mouth (33°30'S 27°08'E) - September 1990, November 1992

#### **Winter rainfall region:**

Sites were established in the winter-rainfall region of the Western Cape at the following localities:

- 1) Hillside Farm (20km from Caledon on route to Napier) (34°20'S 19°38'E)
- 2) Joubertsdal Farm (18km West of Swellendam on route to Ashton) (33°59'S 20°16'E)
- 3) Kweekkraal Farm (Riversdale vicinity) (34°06'S 21°10'E)
- 4) Nachtwacht farm (8km South of Bredasdorp) (34°35'S 20°07'E)
- 5) Potberg Mountain (34°22'S 20°33'E)

The Joubertsdal site was at the edge of an alien blue-gum plantation. The remaining sites were within primarily natural, tall scrub partially invaded by alien *Acacia* or blue-gum trees.

The sites in this region were established in June 1993 and were monitored every six weeks for one year (until May 1994). None of the localities in this region had particularly high densities of bridal creeper and consequently the first 10 plants located were selected for monitoring. A numbered stake was placed at the base of each plant. A record of the parameters listed above for the a-seasonal rainfall region was made.

#### **Summer rainfall region:**

Bridal Creeper was monitored only at irregular intervals in the summer rainfall region. The parameters listed above were recorded for the first 20 plants located at each of the following localities. The dates that monitoring took place are listed.

- 1) Tendele ( $28^{\circ}43'S$   $28^{\circ}56'E$ ) - February 1991, March 1992, October 1992
- 2) Giants Castle Reserve ( $29^{\circ}16'S$   $29^{\circ}31'E$ ) - June 1990, February 1991, March 1992, October 1992
- 3) Garden Castle Reserve ( $29^{\circ}45'S$   $29^{\circ}14'E$ ) - April 1990, February 1991, March 1992, October 1992
- 4) Ncwadi Siding ( $29^{\circ}48'S$   $30^{\circ}06'E$ ) - February 1991, March 1992
- 5) Kaapsehoop Reserve ( $25^{\circ}31'S$   $30^{\circ}47'E$ ) - February 1991, March 1992
- 6) Pilgrims rest ( $24^{\circ}56'S$   $30^{\circ}48'E$ ) - February 1991, March 1992
- 7) Paradise Camp ( $24^{\circ}52'S$   $30^{\circ}53'E$ ) - February 1991, March 1992
- 8) Tzaneen ( $23^{\circ}54'S$   $29^{\circ}56'E$ ) - February 1991, March 1992
- 9) Barberton ( $25^{\circ}43'S$   $31^{\circ}01'E$ ) - February 1991
- 10) Magaliesberg ( $25^{\circ}52'S$   $27^{\circ}26'E$ ) - March 1992

### **Results**

#### **A-seasonal rainfall region:**

In the a-seasonal rainfall region of the Western Cape, production of new shoots peaked in February 1992 (Fig 2.1a). This trend was not apparent in February 1991 because several new shoots were overlooked. In February 1992 excavations down to the tuber mass of all individuals being monitored revealed large numbers of new shoots at the tuber mass. Many new shoots were overlooked in February 1991 as they were still below the surface and consequently were only recorded at the next monitoring occasion in May 1991 (see Fig 2.1a). At times new shoots emerge at a considerable distance from the tuber mass and unless these shoots are traced back to the tuber mass by excavating them, they may be overlooked as belonging to neighbouring bridal creeper plants.

Above-ground growth of bridal creeper is present throughout the year in the a-seasonal rainfall region of the Western Cape, as illustrated by the presence of new growth on all

**Fig. 2.1:** Phenology trends of the widespread form of *Asparagus asparagoides* in the a-seasonal rainfall region of the Western Cape.

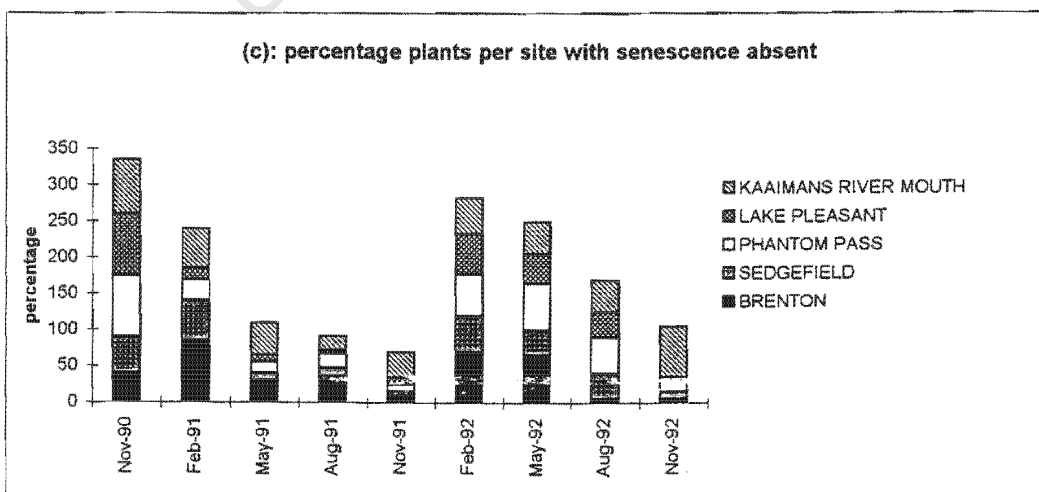
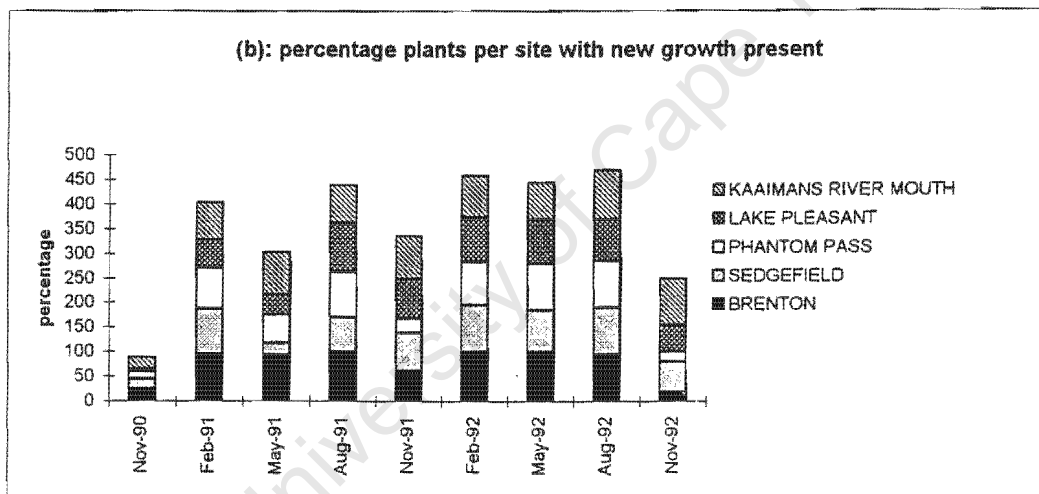
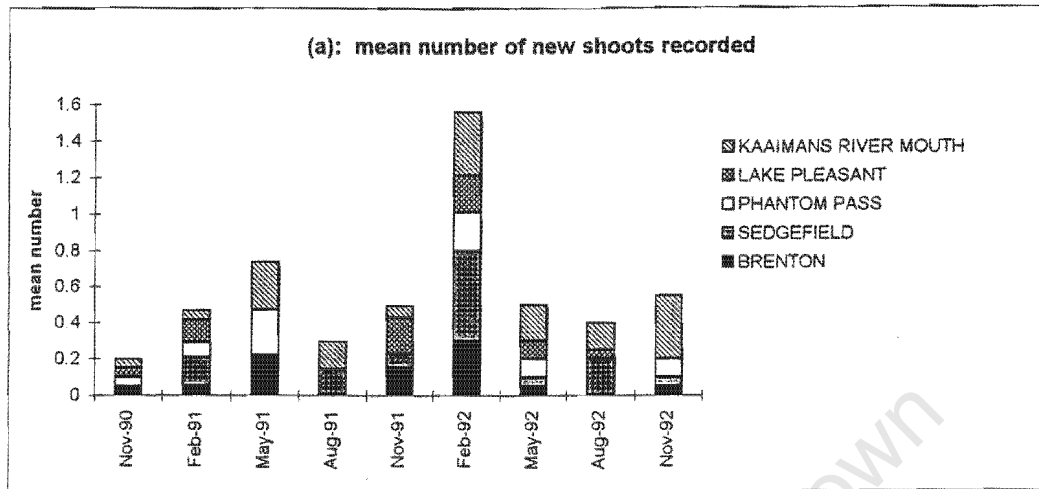


Fig. 2.1 (cont.): Phenology trends of the widespread form of *Asparagus asparagoides* in the a-seasonal rainfall region of the Western Cape.

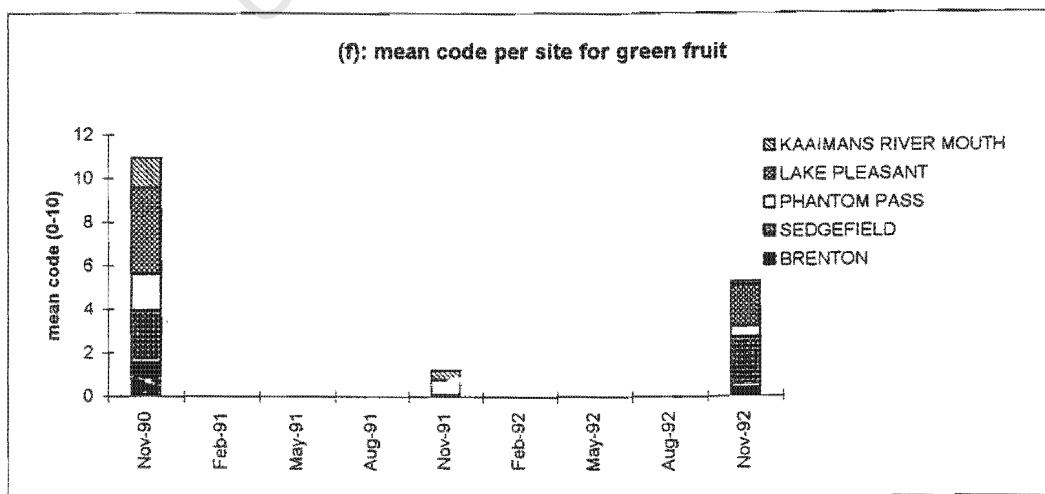
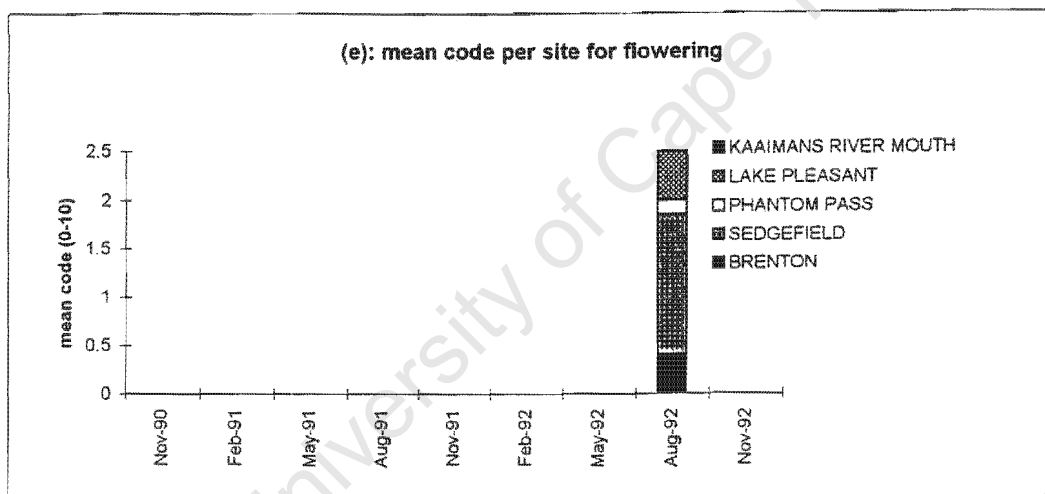
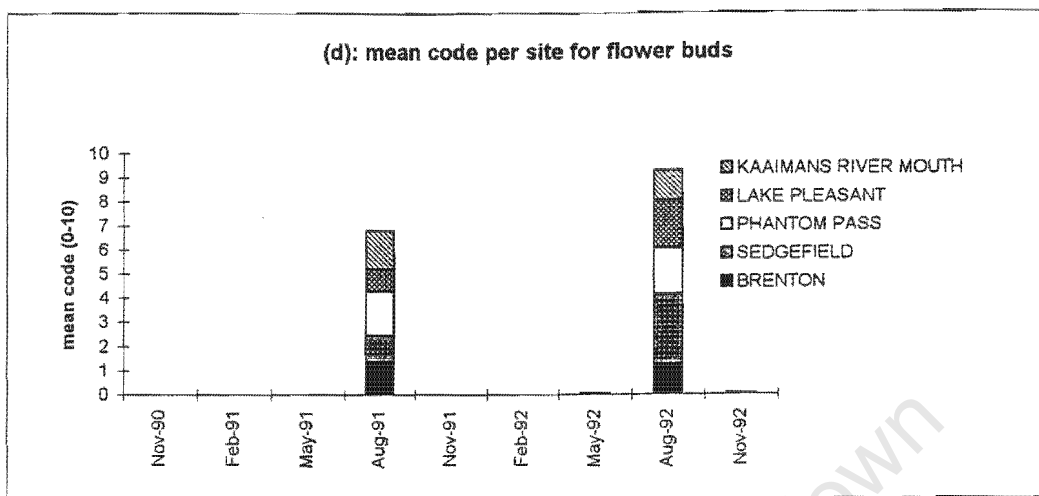
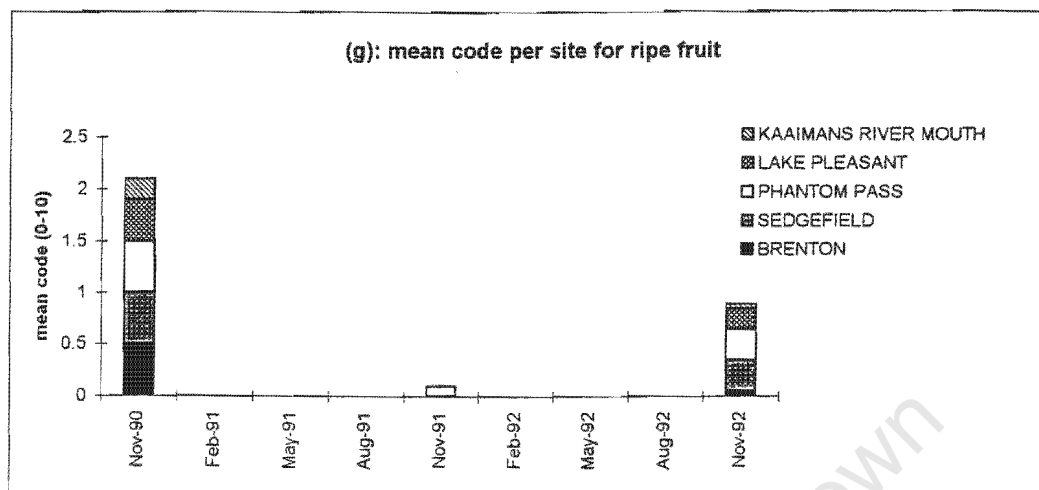


Fig. 2.1 (cont.): Phenology trends of the widespread form of *Asparagus asparagoides* in the a-seasonal rainfall region of the Western Cape.



monitoring occasions (Fig. 2.1b), but there is an approximately annual turnover of stems, with most stems dying between November to February. Fig. 2.1c illustrates that the amount of senescence increases at the sites as the year progresses. The data for November 1990 is an overestimate because this was when the sites were established and plants for monitoring were selected on the basis of live stems being present. Occasionally, stems do not senesce completely, and resprout near the base at the start of the next growing season.

Buds and flowers were recorded in August (Fig 2.1d and e), and fruit in November (Fig 2.1f and g) in this region. Senescence peaked in November, with ripe fruit usually being found on senesced stems. During the 1991 season, large numbers of buds were recorded, but very few flowers or fruits were produced, possibly due to extensive herbivore damage to the foliage. Extensive *Zygina* sp. (Cicadellidae) damage was observed during 1991 (see Chapter 3) and this may possibly have resulted in the virtual absence of flowering and fruiting. Extensive *Zygina* sp. damage significantly reduced fruiting under experimental conditions (see Chapter 5).

The a-seasonal rainfall region of the Eastern Cape was visited irregularly. Ripe fruit was collected at 5 localities in November 1992. At one site, green fruit and some buds and flowers were recorded in September. This suggests that the phenology is equivalent to that of the a-seasonal rainfall region of the Western Cape.

#### **Winter rainfall region:**

Production of new shoots was initiated in January and continued in February, well before the onset of the rainy season (Fig. 2.2a). By June, bridal creeper growth was vigorous, and flower buds had been initiated (Fig. 2.2b). Budding and flowering peaked in July (Fig. 2.2b and c), and by September both green and ripe fruit were present (Fig. 2.2d and e). Fruit was still present in November, but by December senescence was complete (Fig 2.2f). The flowering and fruiting phenology was similar to that occurring in the a-seasonal rainfall region of the Western Cape with the notable exception that senescence is absolute in the winter rainfall region while in the a-seasonal rainfall region some growth is present throughout the year.

#### **Summer rainfall region:**

Surveys in the summer rainfall region were undertaken irregularly, efforts were made to coordinate these surveys with the expected time of fruiting. The phenology of bridal creeper was not as distinct in the summer rainfall region as in the other rainfall regions. Fruit was observed at two times of the year, in February/March, towards the end of the summer rainfall season, and in October, which is at the start of the rainy season. Although many plants

Fig. 2.2: Phenology trends of the widespread form of *Asparagus asparagoides* in the winter rainfall region of the western Cape.

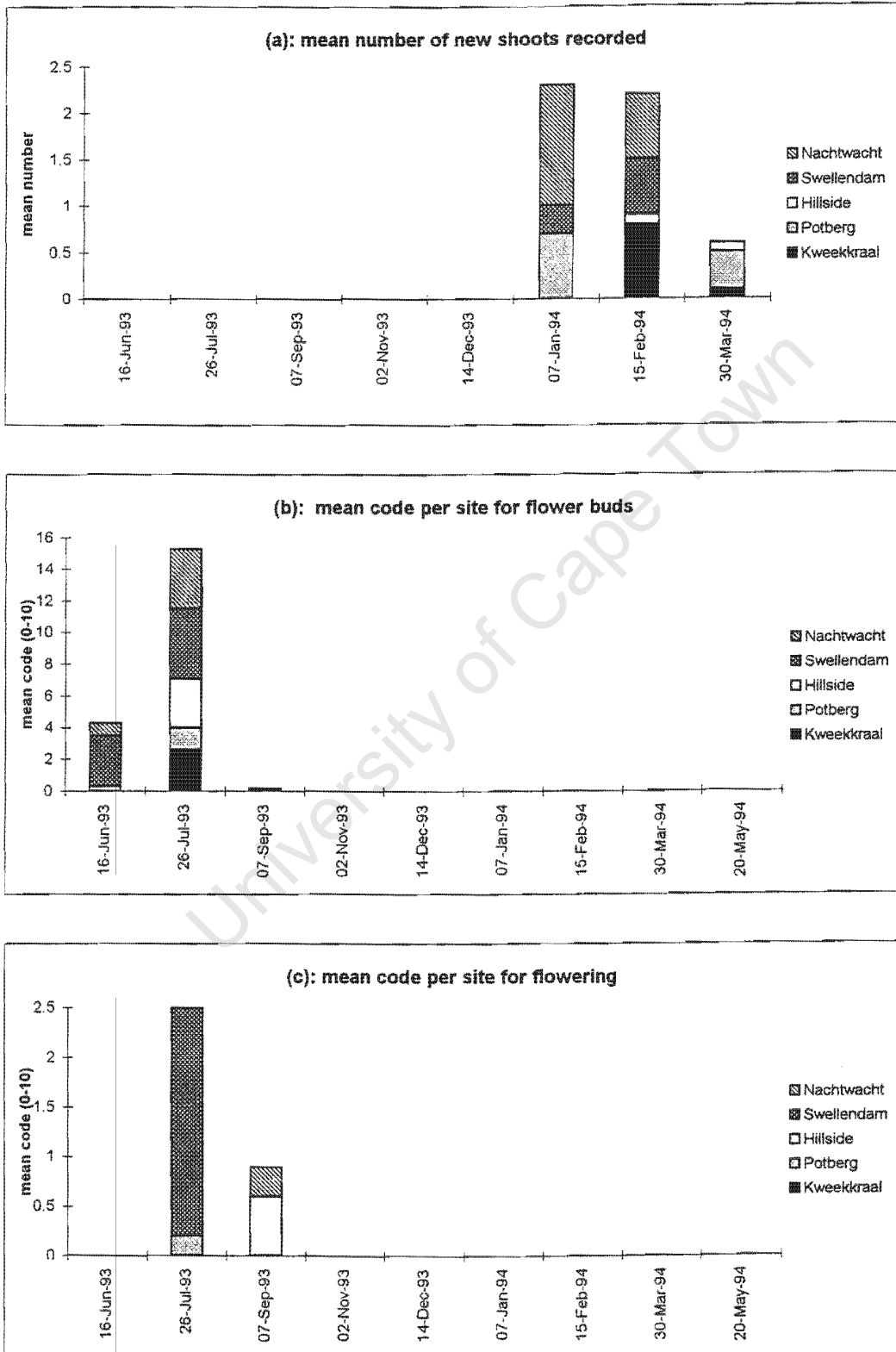
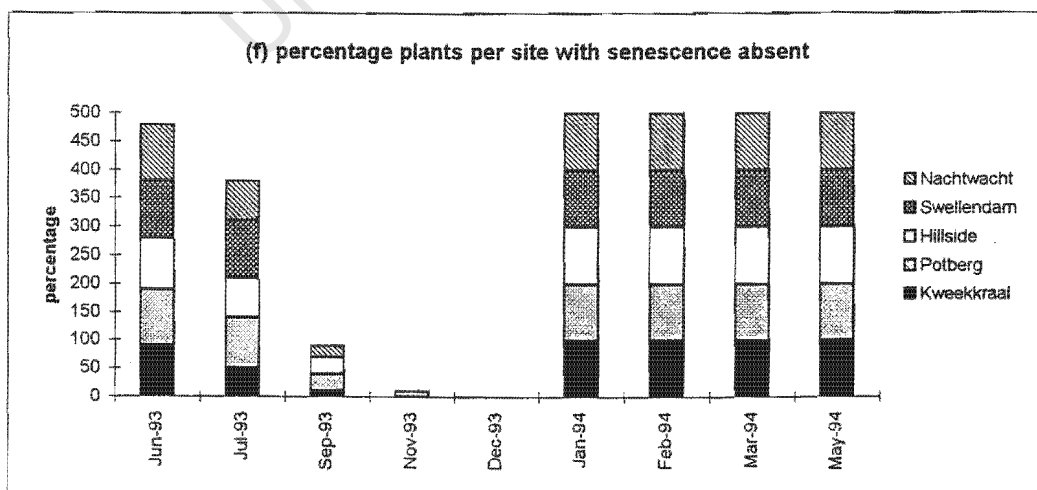
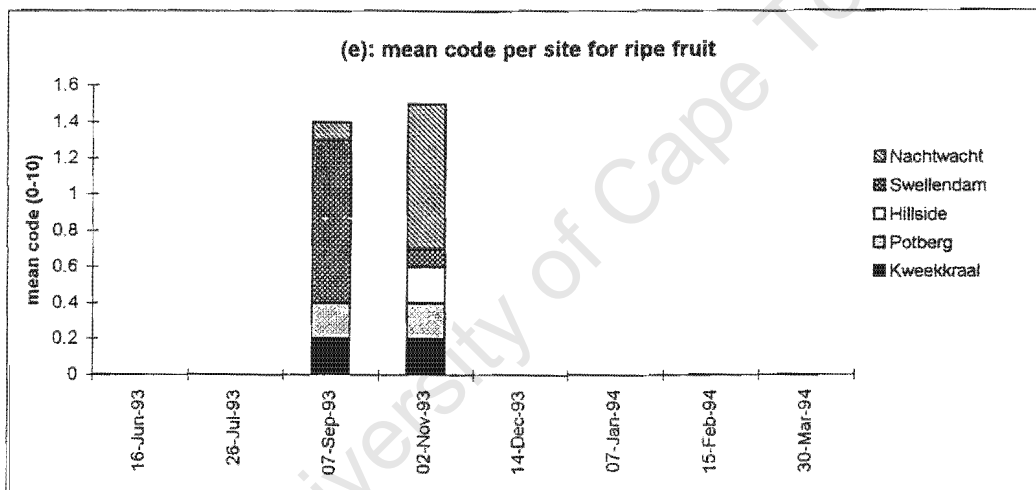
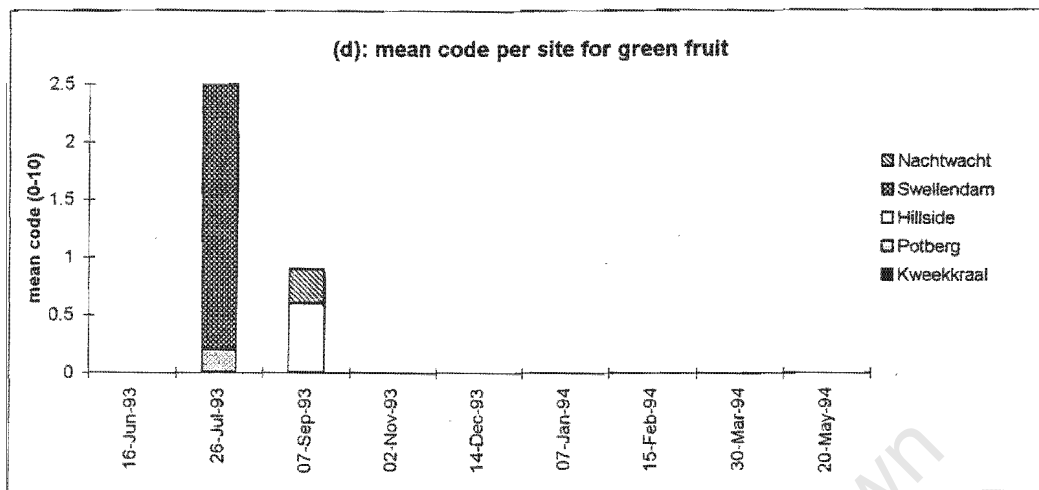


Fig. 2.2 (cont.): Phenology trends of the widespread form of *Asparagus asparagoides* in the winter rainfall region of the western Cape.



fruited in March and senesced completely in the winter (K. Gambol, pers. comm.), apparently not all plants did so. Some plants grow in particularly mesic sub-habitats, such as along stream banks, and it is not clear whether these plants fruit twice in a year, or only in October/November, as bridal creeper does in the other rainfall regions of southern Africa.

### Discussion

Bridal creeper adjusts its phenology to senesce in the dry season, although if adequate moisture is available, senescence may not be complete (as in the a-seasonal rainfall region of the Western Cape) and possibly in more mesic micro-habitats within the summer rainfall region. Fruiting in all rainfall regions was in early summer, although there may possibly be two fruiting seasons in the summer rainfall region.

Prior to the establishment of bridal creeper sites in the winter rainfall region of the Western Cape, a monitoring programme had been established in this region on the south-western Cape form of *A. asparagoides*. When it became apparent that this is not the form of *A. asparagoides* which occurs in Australia extensive surveys were undertaken within the winter rainfall region to establish sites where the widespread form of *A. asparagoides* (bridal creeper) occurs. This was imperative, as much of the distribution of bridal creeper in Australia is presently restricted to winter rainfall regions. It is essential that organisms selected for use in a biological control programme against bridal creeper in Australia are able to withstand the conditions in this type of rainfall region. Possibly the most significant consequence, for the natural enemies associated with bridal creeper in the winter rainfall region, is the complete senescence of above ground growth in summer. In South Africa, bridal creeper, occurs in winter, a-seasonal and summer-rainfall regions, suggesting that it has the potential to spread into these rainfall regions in Australia. Searches for natural enemies associated with bridal creeper were conducted throughout the plant's distribution in South Africa.

## Chapter 3

### Natural enemies associated with vegetative growth of bridal creeper in southern Africa and their potential for use as biological control agents in Australia

#### Introduction

Bridal creeper has an extensive tuber mass providing reserves for growth. Repeated removal (by mechanical means or herbicide) of the above-ground growth of bridal creeper is therefore needed to kill the plant (Robertson, 1983, Pritchard, 1991). An organism, sufficiently specific to bridal creeper, that directly attacks the tuber system and causes its death would be highly desirable for use in a biological control programme against this plant. However organisms attacking the above ground parts of the plant may limit growth of tuber mass reserves and may impact negatively on fruit and seed production. A reduction in fruit and seed production should slow the spread of bridal creeper into previously uncolonised sites in Australia. Several phytophagous species were found on bridal creeper (see Appendix 3) but only those considered to be potentially valuable for biological control purposes are dealt with in this chapter. These are two undescribed species of *Crioceris* (Chrysomelidae), an undescribed species of *Zygina* (Cicadellidae) and the rust fungus *Puccinia myrsiphyllii* (Thuem.) Wint..

#### Methods

Although the search for potential biological control agents of bridal creeper has concentrated on the widespread form of *A. asparagoides* (bridal creeper), all other species previously in the genus *Myrsiphyllum* (see Obermeyer 1984) were examined when encountered during surveys that were described in Chapter 1.

Study sites were established at various localities throughout the range of bridal creeper in southern Africa. The sites and frequency with which they were monitored are given in Chapter 2. During monitoring of individual plants at the various sites observations were made on the associated natural enemies, the amount of damage inflicted by the various organisms was estimated and allocated a code ranging between (0=no damage and 10=extensive damage). During the course of the surveys, the tuber masses of neighbouring plants were exposed by digging down to the tuber mass and searches were made for indications of tuber damage. When the surveys in the a-seasonal rainfall region of the Western Cape were terminated, the plants that were monitored during the survey were excavated and examined for indications of tuber and rhizome damage.

Insects were allocated an accession number (AcUCT = Accession number University of Cape Town) and sent to the Biosystematics Division of the Plant Protection Institute in Pretoria for identification, details of identifications received are listed in Appendix 3.

## Results and discussion

### *Crioceris* species:

Two chrysomelids from the genus *Crioceris* have been found in association with bridal creeper. The specimens (*Crioceris* sp. 1 AcUCT 375, *Crioceris* sp. 2 AcUCT 380) are lodged with the National Collection of Insects in Pretoria. Both are, as yet, undescribed but the biology of these species is similar to that of the European species, *Crioceris asparagi*, which is a pest of commercial asparagus in Europe and North America.

The eggs of both *Crioceris* species associated with bridal creeper are black, approximately 1,5mm long and elongate, they are attached individually at the base to new growth. Although each egg is attached individually to the plant, the eggs are often laid in groups. Newly emerged larvae are pale grey in colour, older larvae are black (Fig 3.1a). The adult of *Crioceris* sp. 2 is illustrated in Fig. 3.1b. The eggs are always laid on young buds and shoots, the presence of soft new growth is needed for survival of newly emerged larvae. Older larvae and adults also eat new growth but are able to eat young cladodes. Pupation occurs in a cell, in the soil at the base of the plant, the cell is formed from a foam like substance which hardens and is pale cream to yellow in colour.

The distribution of the two *Crioceris* species associated with bridal creeper is given in Appendix 4 and Fig. 3.2. *Crioceris* sp. 1 was only recorded at two localities in Kwazulu-Natal in the summer rainfall region of southern Africa. More surveys are needed in this region to provide a more comprehensive distribution of this species. Eggs and adults of *Crioceris* sp. 1 were also collected on *A. ramosissimus* Baker (previously in *Myrsiphyllum*). *Crioceris* sp. 2 was recorded in the a-seasonal rainfall region of the Eastern Cape and Western Cape and in the winter-rainfall region of the Western Cape. (Appendix 4, Fig. 3.2). Eggs, larvae and adults of this species were also recorded on another *Asparagus* species (probably *A. densiflorus* (Kunth) Jessop).

As the distribution of *Crioceris* sp. 2 tends to be clumped and individuals aggregate on a few plants within an area, their presence at a site at any time may be substantially under-represented by only recording those present on monitored plants. However, within the a-seasonal rainfall region of the Western Cape the presence of *Crioceris* sp. 2 (either eggs, larvae or adults) was noted on every survey occasion (February, May, August and November) and reflects the fact that in this region there is new growth available throughout

**Fig 3.1:** Larva **(a)** and adult **(b)** of *Crioceris* sp. 2 which has been recorded on the widespread form of *Asparagus asparagoides* in the a-seasonal and winter rainfall regions of South Africa.

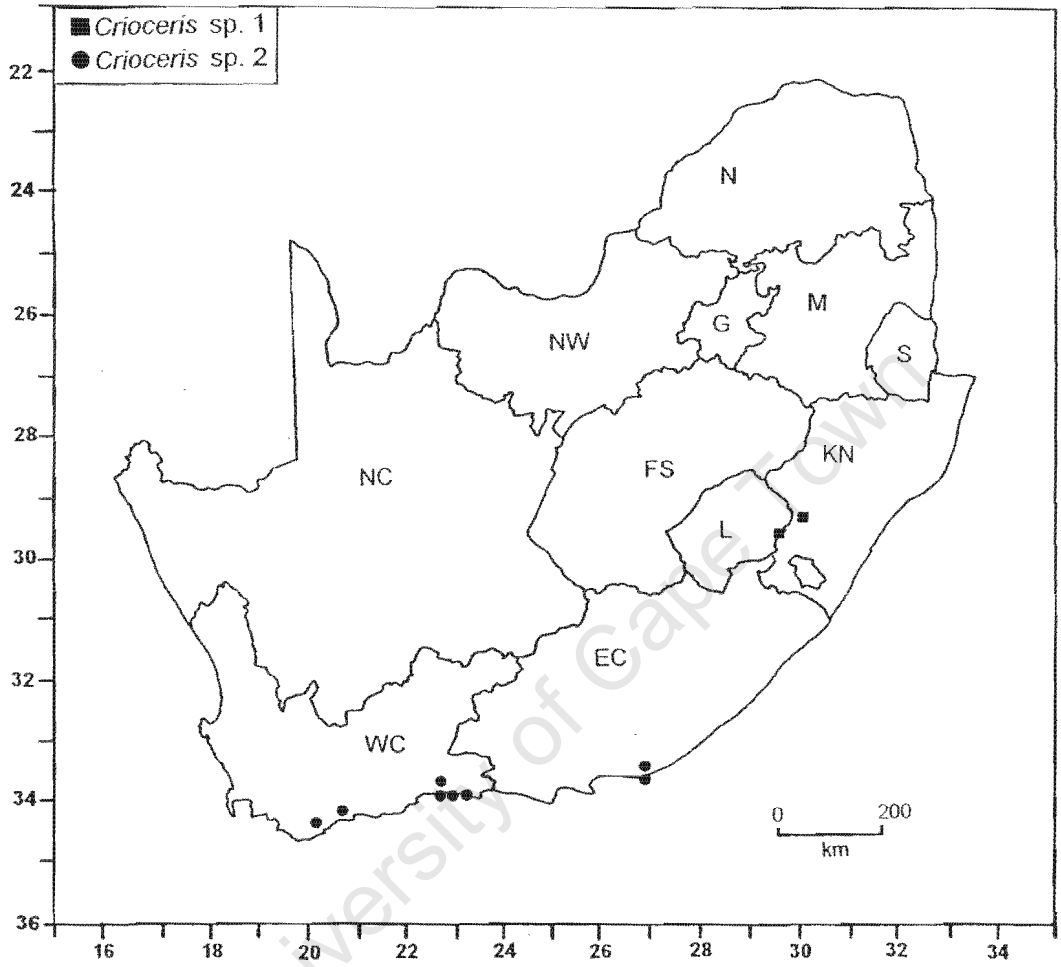


**(a)**



**(b)**

**Fig 3.2:** The distribution of *Crioceris* spp. 1 and 2 associated with the widespread form of *Asparagus asparagoides* in South Africa.  
 (WC = Western Cape, NC = Northern Cape, EC = Eastern Cape, FS = Free State, NW = Northwest, N = Northern Province, G = Gauteng, M = Mpumalanga, KN = Kwazulu-Natal, L = Lesotho, S = Swaziland.)



the year. However, the abundance of *Crioceris* sp. 2 varied substantially between years. When the surveys commenced in November 1990, only one larva was found at one locality. By contrast, in August 1991 a total of 11 larvae were found on survey plants at four of the localities and in August 1992 there were no larvae on survey plants although eggs and adults were noted on the survey plants at one site. Extensive searches to collect eggs, larvae or adults of *Crioceris* sp. 2 were conducted, to enable the establishment of a laboratory culture. At times, it was extremely difficult to find any evidence of this species, while on other occasions the species was abundant. Rearing of field-collected larvae in the laboratory revealed that larvae were parasitized by a gregarious Eulophid parasitoid wasp (AcUCT 379) and an unidentified tachinid fly. Levels of parasitism were not quantified.

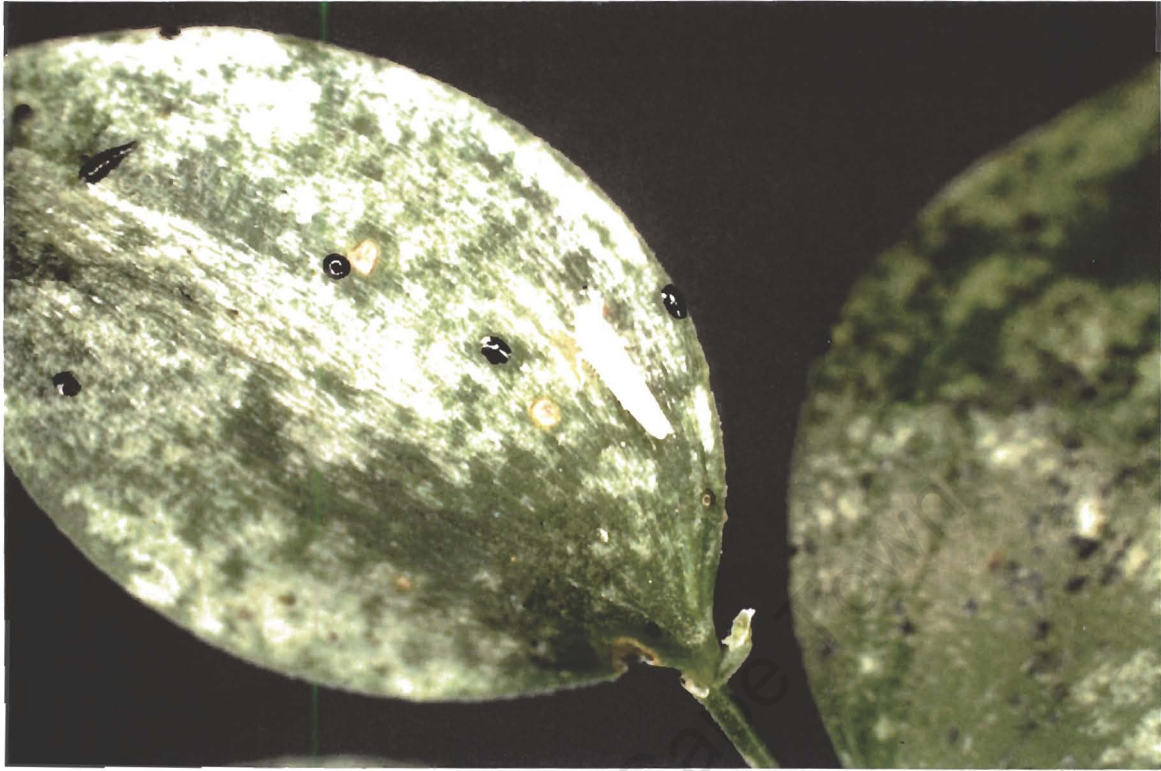
In the winter rainfall region of the Western Cape the above ground growth of bridal creeper senesces in late summer, but new shoots appear in January/February, well before the onset of the winter rains. Eggs and adults of *Crioceris* sp. 2 were recorded in February. Eggs were also recorded in June, suggesting that there may be more than one generation per season. Larvae were recorded in May, June and July.

As most of the bridal creeper infested areas in Australia occur in winter rainfall regions, it is imperative that potential agents have the ability to cope with complete senescence of above-ground growth in summer. The presence of *Crioceris* sp. 2 in the winter rainfall region illustrates its ability to cope with these environmental conditions and enhances its potential as a biological control agent for use against bridal creeper in Australia. Indications of high levels of parasitism in southern Africa also suggest that if released from parasitism significant population levels may be achieved in Australia. The fact that *Crioceris* sp. 2 has a biology very like that of a pest of commercial asparagus suggests that it has the capacity to be very damaging. Indeed, Syrett et al. (1996) suggest that "Chrysomelid groups that include pests of crop plants may also be good sources of weed biological control agents". *Crioceris* sp. 2 has not been recorded as a pest of commercial asparagus in South Africa but its potential impact on commercial asparagus in Australia will need to be assessed. In South Africa there is not significant overlap between regions where commercial asparagus is cultivated and the distribution of bridal creeper.

#### ***Zygina* species (Cicadellidae):**

Extensive damage is caused to the cladodes of bridal creeper by an undescribed *Zygina* species (Cicadellidae). An adult of this species, and the type of damage inflicted to the cladodes of bridal creeper, are shown in Fig. 3.3. Eggs are laid under the epidermis of the cladode. Nymphs and adults feed on the cladodes leaving distinctive clear patches (Fig. 3.3). The damage inflicted by the *Zygina* species is usually easy to identify, although similar damage is caused by several polyphagous organisms, *Hercinothrips bicinctus* (Bagnall)

**Fig 3.3:** Adult and characteristic damage of *Zygina* sp. (Cicadellidae) associated with both forms of *Asparagus asparagoides* in South Africa.



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(banana thrips) (AcUCT 372), *Halotydeus destructor* (Tucker) (red-legged earth mite)(AcUCT 373) and *Tetranychus cinnabarinus* (Boisduval) (red spider mite). However, under close scrutiny, the types of damage inflicted by each of these organisms is discernible. Evidence of damage attributable to the *Zygina* species may be obscured by the rust fungus, *Puccinia myrsiphyllii*.

The distribution of *Zygina* sp. is given in Appendix 4 and Fig. 3.4. The insect occurs throughout the range of bridal creeper in southern Africa and in all three rainfall regions. A small white Cicadellid, which appears identical to that found on bridal creeper, was also recorded during the surveys on the south-western Cape form of *A. asparagoideus* as well as on *A. kraussianus*, *A. multituberosus* and *A. ovatus*, these *Asparagus* species were previously in *Myrsiphyllum* (Appendix 4, Fig 3.4).

The damage inflicted to the cladodes of bridal creeper by successive generations of *Zygina* sp. cumulates during the life-span of the stems of bridal creeper. Consequently, in the a-seasonal rainfall region of the Western Cape where there is an approximately annual turnover of stems with die-off of most stems occurring after fruiting in November and a peak in the production of new stems in February, damage increases as the year progresses (Fig. 3.5a). This trend was obscure in 1991, possibly as a result of premature senescence of stems induced by high levels of *Zygina* sp. damage, (see senescence data given in Fig. 2.1c (Chapter 2)).

In 1991, the amount of damage inflicted by *Zygina* sp. in the a-seasonal rainfall region was particularly severe (Fig. 3.5a). At the end of the year (November 1991), very few fruits were noted in this region and it is possible that this was a direct result of high *Zygina* sp. damage levels (see Chapter 5 for an investigation of the effect of *Zygina* sp. damage on reproduction of bridal creeper).

In the winter-rainfall region of the Western Cape where complete senescence of bridal creeper occurs and re-growth is initiated in late summer, damage inflicted by *Zygina* sp. was noted soon after re-growth had been initiated and the level of damage increased throughout the growing season (Fig. 3.5b). By November senescence was advanced and consequently the evidence of *Zygina* sp. damage was less marked. However, the damage levels were not as high as recorded for bridal creeper in the a-seasonal rainfall region during 1991.

Evidence of extremely high levels of damage inflicted by *Zygina* sp. on bridal creeper in southern Africa, and the fact that the insect occurs in all three rainfall regions made *Zygina* sp. a very promising candidate for use in a biological control programme against bridal creeper and, in May 1999, it was released in Australia (Wills 1999).

**Fig 3.4:** The distribution of *Zygina* sp (Cicadellidae) associated with both forms of *Asparagus asparagoides* and other *Asparagus* (previously *Myrsiphyllum*) spp. in South Africa. (WC = Western Cape, NC = Northern Cape, EC = Eastern Cape, FS = Free State, NW = Northwest, N = Northern Province, G = Gauteng, M = Mpumalanga, KN = Kwazulu-Natal, L = Lesotho, S = Swaziland.)

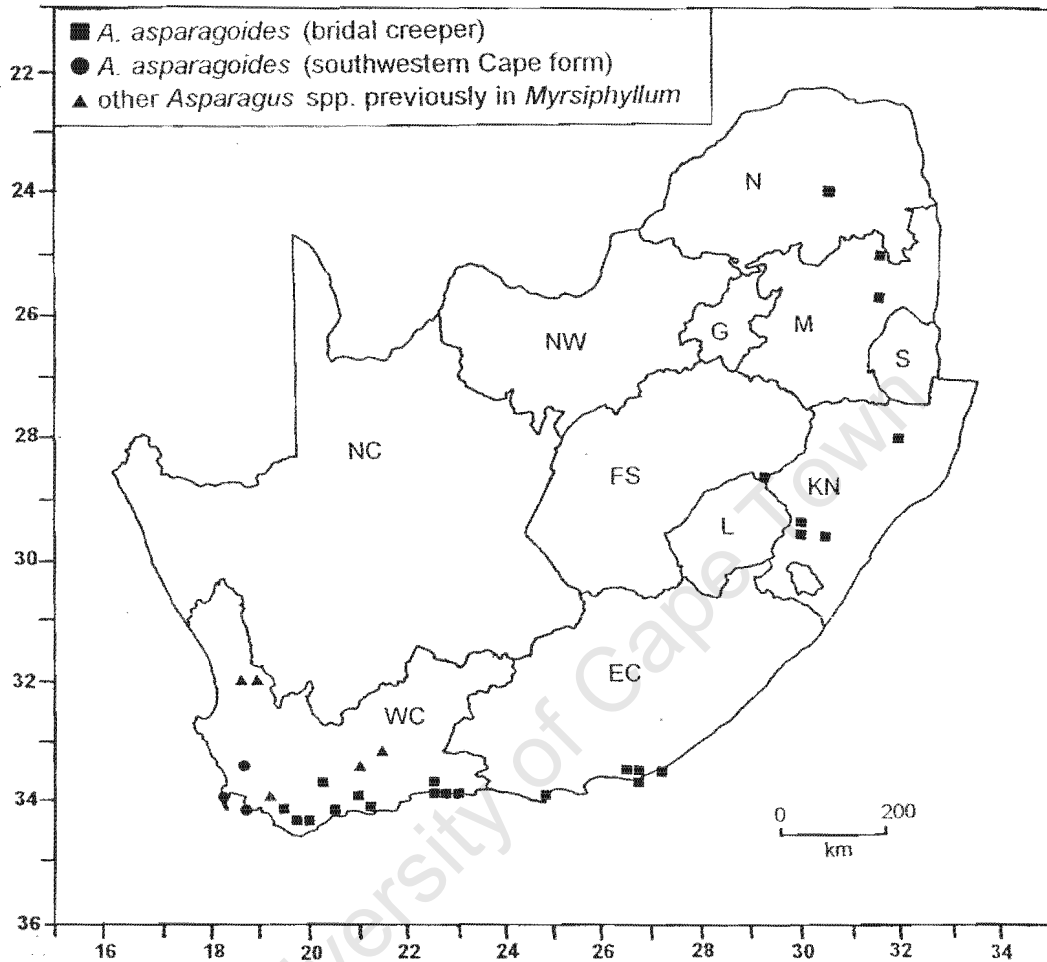
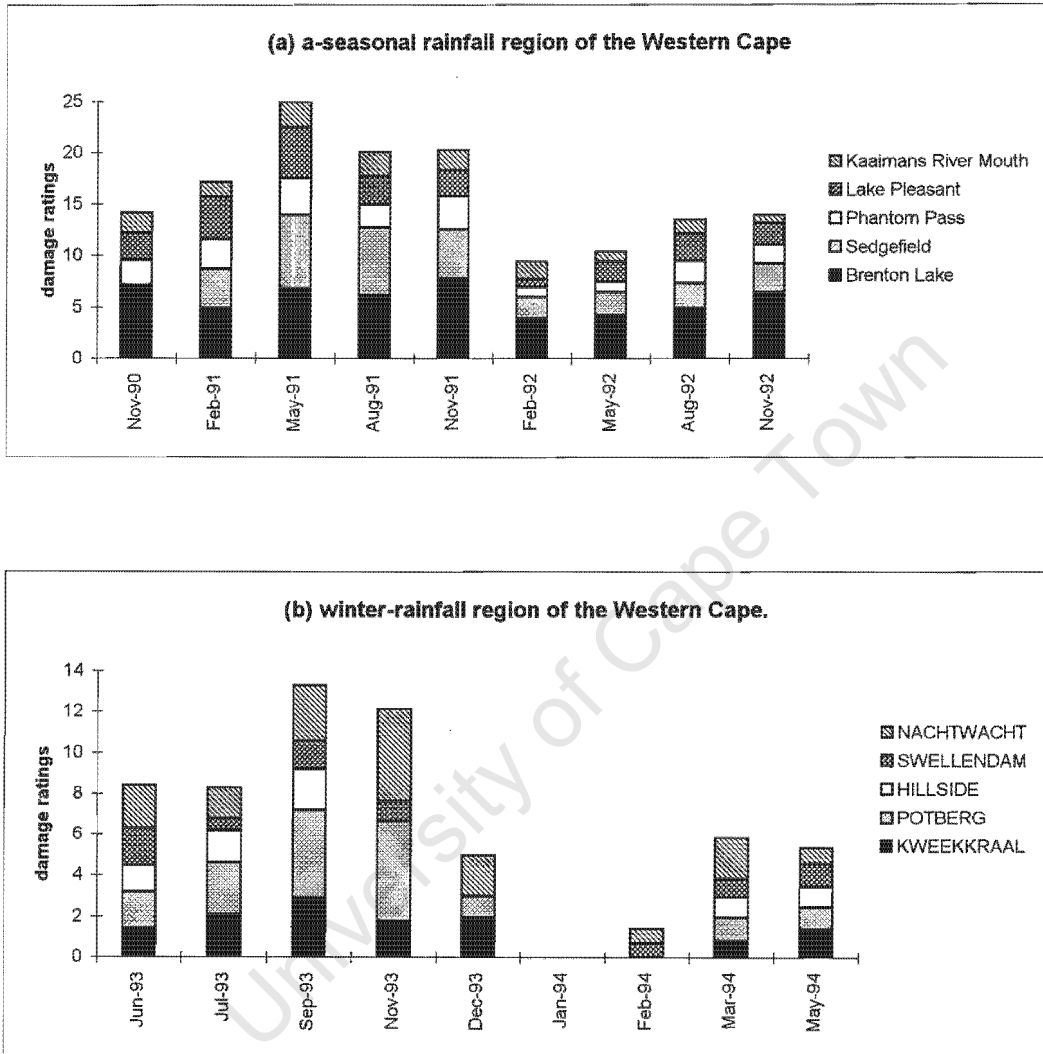


Fig. 3.5: Levels of damage to the widespread form of *Asparagus asparagoides* attributable to *Zygina* sp. (Cicadellidae) in (a) the a-seasonal rainfall region of the Western Cape (over two years) and (b) in the winter rainfall region of the Western Cape (over one year).



### ***Puccinia myrsiphylli* (cladode rust):**

The species name of the rust fungus (*P. myrsiphylli*) derives from the fact that its host plant, the widespread form of *A. asparagoides*, was previously in the genus *Myrsiphyllum*. It is macrocyclic and autoecious and attacks the cladodes and stems of bridal creeper (Doidge 1926). *Puccinia myrsiphylli* on cladodes of bridal creeper is illustrated in Fig. 3.6.

The distribution of *P. myrsiphylli* on the widespread form of *A. asparagoides* in South Africa is given in Fig. 3.7 and Appendix 4. *Puccinia myrsiphylli* was recorded throughout the range of bridal creeper (at altitudes ranging between sea-level and 1800m) and in all three rainfall regions. Extensive observations were made on all other '*Myrsiphyllum*' species with the exception of *A. juniperoides* Engl. which was only located on 3 occasions due to the restricted nature of its distribution and growing season. *Puccinia myrsiphylli* was also recorded on *A. volubis* and *A. alopecurus* (Oberm.) Malcomber & Sebsebe. The aecidial stage of a rust which may have been *P. myrsiphylli* was recorded on *A. ovatus*. Based on examination of the urediospores, differences in the forms of *P. myrsiphylli* recorded on the various plant species were discernible (M.J. Morris, Plant Protection Research Institute, Stellenbosch, pers. comm). The distribution of *P. myrsiphylli* on '*Myrsiphyllum*' species other than the widespread form of *A. asparagoides* is also given in Fig. 3.7. Despite extensive surveys, *P. myrsiphylli* was not recorded on the south-western Cape form of *A. asparagoides*. The distribution of the two forms of *A. asparagoides* overlaps in the region between Caledon and Albertinia and while *P. myrsiphylli* was abundant on the widespread form of *A. asparagoides* in this region it was absent from the south-western Cape form of the species, suggesting that the south-western Cape form of *A. asparagoides* may be resistant to *P. myrsiphylli*.

The fungus was also never recorded on *Asparagus kraussianus* even when a rust-infected bridal creeper was growing intertwined with this species.

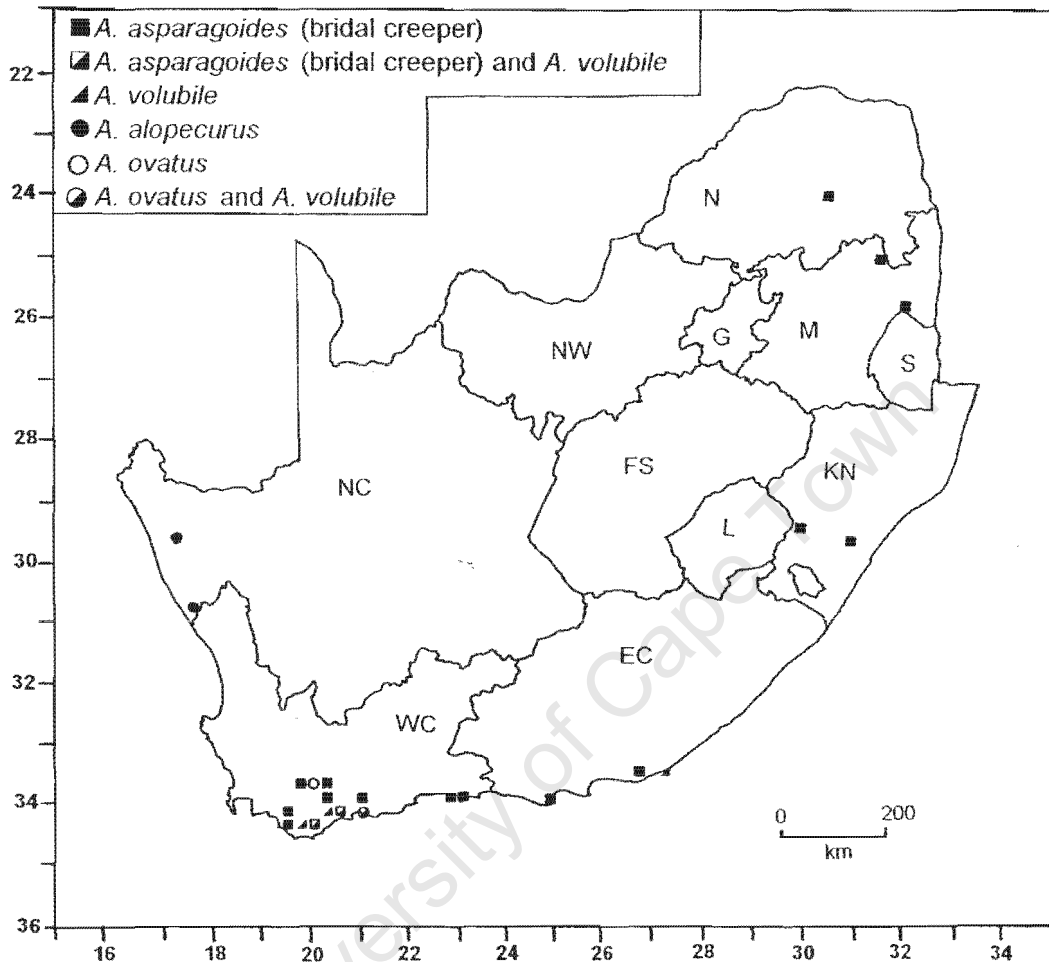
In the winter rainfall region of the Western Cape, above-ground growth of bridal creeper is present through most of the year, except at the height of summer. Plants resprout towards the end of summer ahead of the start of the rainy season. The phenology of the plants and of *P. myrsiphylli* in the winter rainfall region, were recorded between June 1993 and May 1994, the results are presented in Fig. 3.8a. *Puccinia myrsiphylli* is well adapted to the plants phenology, with the amount of rust (urediospores) on the plants increasing during winter and spring, and teliospores being produced in spring to enable the rust to survive over the dry summer period (L. Morin, CSIRO, Canberra, Australia, pers. comm.). The first evidence of rust was observed within 12 weeks of the appearance of new shoots in late summer.

**Fig 3.6:** The rust fungus *Puccinia myrsiphylli* on the cladodes of the widespread form of *Asparagus asparagoides*.



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**Fig 3.7:** The distribution, within South Africa, of the rust fungus *Puccinia myrsiphylli* on *Asparagus asparagoides* and other species of *Asparagus* previously in *Myrsiphyllum*. (WC = Western Cape, NC = Northern Cape, EC = Eastern Cape, FS = Free State, NW = Northwest, N = Northern Province, G = Gauteng, M = Mpumalanga, KN = Kwazulu-Natal, L = Lesotho, S = Swaziland.)



In the a-seasonal rainfall regions of South Africa, above-ground growth of *A. asparagoides* is present throughout the year. Although complete senescence does not occur the phenology is similar to that in the winter rainfall region. Senescence peaks in mid-summer and new shoots appear in late summer. There is an approximately annual turnover of stems. The phenology of *P. myrsiphylli* and of bridal creeper in the a-seasonal rainfall region was recorded over 2 years (November 1990 to November 1992) the results are presented in Fig. 3.8b. The phenology of *P. myrsiphylli* was not as distinct as in the winter rainfall region, possibly because the permanent availability of foliage caused greater overlap in rust generations and consequently less synchronisation with the phenology of the host. High damage levels were recorded in November 1990 and 1992 (i.e. spring) as for the winter rainfall region but were absent in November 1991. High levels of damage attributable to *Zygina* sp. were recorded in this rainfall region during 1991 (see Fig. 3.5a) and this may have impacted negatively on *P. myrsiphylli* populations. The results from the a-seasonal rainfall region demonstrate that populations of *P. myrsiphylli* may vary substantially between years (Fig. 3.8b).

The occurrence of *P. myrsiphylli* in the summer rainfall region is summarised in Table 3.1. This region was visited infrequently, usually in late summer, towards the end of the rainy season. *Puccinia myrsiphylli* was noted at six of the ten sites in this region. Substantial rust infestations were noted repeatedly at various sites in late summer but we are unable to comment on the phenology of the rust in this region. The fungus was recorded in mid-winter (Giants Castle, June 1990) on plants within the bounds of the gardens at the rest camp which received supplementary watering, plants were not located outside the confines of the rest camp gardens on this occasion as this was the dry season and it is assumed that the majority of the plants occurring under natural conditions had senesced.

*Puccinia. Asparagi* DC., is a pest on commercial asparagus, *A. officinalis* in Europe and North America. Experimental evidence has shown that strains of *A. officinalis* more susceptible to *P. asparagi*, show reduced production of 'spears' (growth tips) relative to rust resistant commercial asparagus strains (Johnson and Lunden 1992). The related *P. myrsiphylli*, may be expected to similarly have a substantial affect on the growth of *A. asparagoides*.

Several *Puccinia* spp. have been utilized, or are under consideration, as biological control agents (Hasan, 1988, Julien 1992). Rust fungi are considered to have excellent biological control potential (Morin and Syrett, 1996). One of the foremost examples is the biological control of the narrow leaf form of skeleton weed (*Chondrilla juncea* L. (Asteraceae)) with the rust fungus *Puccinia chondrillina* Bubak and Sydenham (Uredinales) in Australia (Hasan 1988).

**Fig. 3.8:** Phenology trends of the rust fungus *Puccinia myrsiphylli* on the widespread form of *Asparagus asparagoides* in (a) the winter rainfall region of the Western Cape (over one year) and (b) the a-seasonal rainfall region of the Western Cape (over two years). The phenology trends for the rust are super-imposed on the phenology of the widespread form of *A. asparagoides* in the two rainfall regions. The phenology of the plants is indicated by the mean percentage of bridal creeper plants with no senescence ( $\pm$  S.E.) for the five sites in each region.

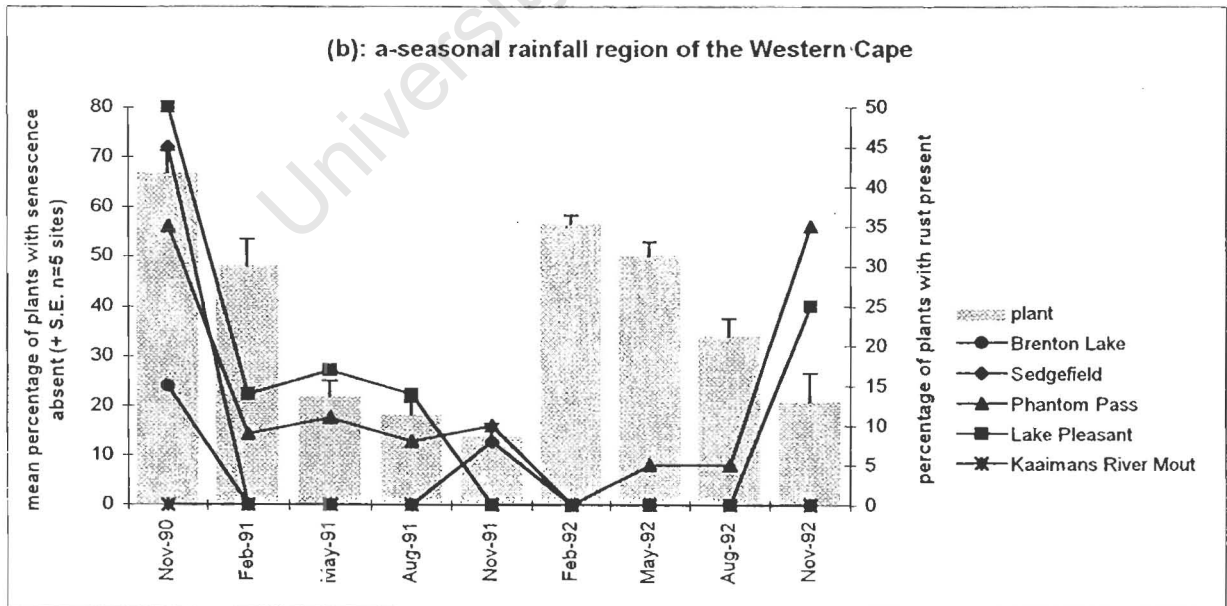
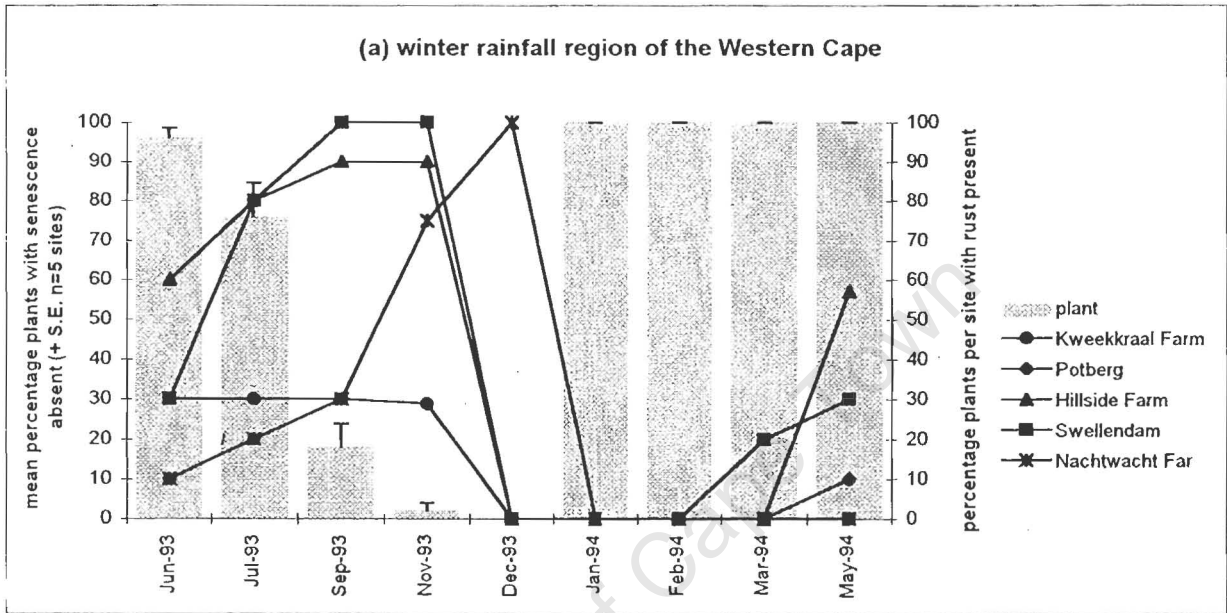


Table 3.1: Summary of the occurrence of *Puccinia myrsiphlli* in the summer rainfall region. (grid references for the localities below are listed in Chapter 2)

Locality	date	code range	code mean	n	% P/A
Giants Castle	Jun-90	2-8	1.9	11/20	55
	Feb-91	1-5	1.6	19/20	95
	Mar-92	1-9	3.8	20/20	100
	Oct-92	0	0	0/20	0
Ncwadi Siding (Byrne)	Feb-91	2-8	3.2	16/20	80
	Mar-92	1-8	3.5	18/20	90
Pilgrims Rest	Feb-91	1-5	0.8	9/20	45
	Mar-92	1-5	1.1	9/20	45
Paradise Camp	Feb-91	1-8	1.2	6/20	30
	Mar-92	1-6	0.8	8/20	40
Magoebaskloof (Tzaneen)	Feb-91	1-9	4.4	19/20	95
	Mar-92	1-5	1.7	16/20	80
Barberton	Feb-91	1-6	1.1	11/20	55

Rust was not recorded during surveys at Garden Castle (Apr-90, Feb-91, Mar-92, Oct-92), Kaapsehoop (Feb-91, Mar-92) and Magaliesberg (Mar-92)

Although many factors may affect the spread and density of *P. myrsiphylli* in Australia, the distribution of the rust within various climatic regions of South Africa including arid winter rainfall regions and high altitude summer rainfall regions suggests that it could be utilised in a wide range of climates. Since many of the bridal creeper infestations in Australia occur in winter rainfall regions (Scott and Kleinjan, 1991), it is pertinent to know that not only can *P. myrsiphylli* survive in this climatic regime, but it is capable of achieving high levels of damage. High levels of damage were also noted in a-seasonal and summer rainfall regions. If plant pathogens are widespread and virulent in their native range, they can be expected to show similar properties after introduction (Hasan, 1988).

If it does not acquire any natural enemies, even higher levels of infestation could be seen in Australia than in South Africa where *P. myrsiphylli* is subject to attack by larvae of a cecidomyid species and a parasitic fungus (L. Morin, CSIRO, Canberra, Australia, pers. comm.)

#### **Other phytophagous species**

A cecidomyid species that attack the growing tips of bridal creeper was recorded (Appendix 3: AcUCT422, 423) in the a-seasonal rainfall region of the Western Cape. These minute flies are capable of considerable damage by causing severe galling and distorting of the growing tips (Fig.3.9). Although the level of specificity is not known, similar galls (caused by the same, or closely related cecidomyid species) were recorded on *Asparagus plumosus* Baker and another *Asparagus* species (probably *Asparagus densiflorus*) but not on non-Asparagaceae growing in the area. A cecidomyid species has not been recorded as a pest of commercial asparagus in South Africa (Annecke and Moran, Daiber, pers comm.). It did not prove possible to establish a laboratory culture of these minute insects. They require fresh growing tips which are only available for a limited time (during autumn). The galls are prone to desiccation or rotting when removed from the plant, and because the new growth of bridal creeper is particularly soft, bagged portions of the plant usually senesce. Attempts to excavate and transport plants with galls, were unsuccessful, as the above ground growth senesced causing the death of the galls. Prior to pupation, the larvae desert the galls to pupate in the soil.

Cecidomyidae species were also reared from galls on the cladodes of *A. plumosus* (AcUCT 395) and *Asparagus falcatus* L. (AcUCT 396), these galls are distinct from the growth tip galls mentioned above. A complex of cecidomyidae may be associated with Asparagaceae in South Africa.

Other Chrysomelidae collected on *A. asparagoides* include a polyphagous species, *Polpoxena praetoriae* (Gahan) (AcUCT 390) which was collected at a single locality in the

**Fig 3.9:** Galling induced on the shoots of the widespread form of *Asparagus asparagoides* by the larvae of an unidentified Cecidomyid.



Magaliesberg mountain range and a flea beetle *Hespera* sp. (AcUCT 389) which was collected at a single locality in the summer rainfall region, this latter species may warrant further investigation.

Adults of a large weevil, *Brachycerus parilis* Haaf (AcUCT 378) were found to feed on the foliage and stems of bridal creeper in the a-seasonal rainfall region of the Western Cape. Extensive nocturnal observations did not reveal this species feeding on other plants (including *Asparagus plumosus* and *Asparagus* prob. *densiflorus*). No weevil larvae were found during extensive excavations and dissections of the tuber masses of bridal creeper. However, an association between this species and bridal creeper is still suspected. Adults of the weevil were encountered rarely and it is possible that the larvae were undetectably scarce. Adults of a second, smaller *Brachycerus* sp., have been noted feeding on the south-western Cape form of *A. asparagoides* (AcUCT 382). Several weevil larvae were also found, at the same localities, in the tubers of the south-western Cape form of *A. asparagoides*. The damage caused by these larvae was considerable. None of the larvae were successfully reared to adults, but it is probable that they are the larvae of the second *Brachycerus* species.

On one occasion a weevil larvae was recorded in the tubers of *A. alopecurus* at Darters Grave (30°18' S 17°54' E). Other large *Brachycerus* spp. adults were noted on *Asparagus* spp. previously in the genus *Protasparagus* (AcUCT 386, 383, 384, 385) suggesting that a complex of *Brachycerus* spp. may be associated with *Asparagus* sp. in southern Africa. An organism directly attacking the tuber system of bridal creeper would be highly desirable for use in a biological control programme and further investigation of the *Brachycerus* spp. may reveal a suitable candidate. The genus *Brachycerus* are commonly called Aloe snout beetles (Annecke and Moran, 1982).

## Chapter 4

### Natural enemies of the fruit and seed of bridal creeper in southern Africa and their potential for use as biological control agents in Australia

#### Introduction

Anderson (1989) discusses the significance of seed predation on stable populations of long-lived perennials. He points out that seed predators may not impact negatively on populations of such plants if the availability of suitable sites for germination and establishment of seedlings is limited. The release in South Africa, for biological control purposes, of a bud-feeding weevil *Trichapion lativentre* (Bèguin-Billecocq) against *Sesbania punicea* (Cav.) Benth. (a perennial tree originating from South America) illustrates this dramatically. This weevil routinely reduced pod production in *S. punicea* infestations in South Africa by more than 98% and although this reduced seedling density within *S. punicea* infestations, long term studies revealed that it did not result in reduced density of mature trees. (Hoffmann and Moran, 1998, 1999). When additional agents were introduced, *S. punicea* was successfully controlled. Hoffman and Moran (1998) advocate the use of agents that reduce seed-set or that destroy the seeds of their host plants as a 'first line of attack in the biological control of weeds' as these agents could be expected to reduce the invasiveness of the weed. Other control agents, or methods, can then be used to impact further on weed populations, hopefully resulting in successful control.

Bridal creeper populations in Australia are still expanding their range and sites suitable for germination and establishment of seedlings can therefore be predicted to be widely available. Bridal creeper seed is bird dispersed, which facilitates colonisation of new sites. The establishment of a natural enemies that attack the fruit and/or seed of bridal creeper could assist in reducing the spread, and possibly the density, of bridal creeper in Australia.

The fruits of bridal creeper and other members of the Asparagaceae in southern Africa are attacked by larvae of a moth, *Zalaca snelleni* (Wallengren) (Noctuidae, Acontiinae). The seeds of bridal creeper are attacked by a *Eurytoma* sp. (Hymenoptera, Eurytomidae). Both of these species have the potential to contribute towards the biological control of bridal creeper in Australia.

#### Methods

##### Distribution of *Z. snelleni* and *Eurytoma* sp. in southern Africa

To determine the distribution and host range of *Eurytoma* sp. and *Z. snallani*, fruit samples were collected from bridal creeper throughout southern Africa. Samples of fruit were also collected from several other *Asparagus* spp. previously in *Myrsiphyllum*, the samples were kept in well ventilated containers and emergence of insects was monitored.

### Identification of species

Specimens reared from the fruit and seeds of bridal creeper and other Asparagaceae were sent to the Biosystematics Division of the Plant Protection Institute in Pretoria for identification. Considerable variation in size of individuals of *Eurytoma* sp. occur and specimens were selected to encompass the entire range of sizes.

### Damage levels attributable to the *Eurytoma* sp

In the a-seasonal rainfall region of the Western Cape an analysis of the impact of *Eurytoma* sp. was conducted over four successive fruiting seasons (November 1990, 1991, 1992, 1993). Five samples of 20 fruits (taken from a single plant) were collected, where possible, per study site (the study sites are listed in Chapter 2). The samples collected during the years 1990 -1992 were maintained in the laboratory until emergence of *Eurytoma* sp. had ceased, the fruits were then dissected under a dissecting microscope and the number of seeds damaged by the wasp recorded. A variable number of seeds are set in bridal creeper and the percentage of seeds damaged by *Eurytoma* sp. was calculated as the percentage of the potentially viable seeds. Several seeds appeared to be aborted in the early stages and were present as flat scale like structures which were occasionally partially sclerotized. These seeds were not viable and were consequently excluded from the analysis. Some samples were damaged by the fruit eating moth, *Z. snallani* and consequently fewer than 20 fruits were available for analysis of *Eurytoma* sp. damage. In November 1993, samples were dissected shortly after collection and prior to the emergence of the wasps, this enabled observations to be made on the prevalence of multiple parasitism by *Eurytoma* sp.

In the winter rainfall region of the Western Cape five samples of 20 fruits were collected at the Nachtwacht site in October 1992 and September 1993, and at the Swellendam site in September 1993. There was very little fruit produced during the 1993 season at the other winter rainfall sites and samples of fruit were not located. Five fruit samples of 20 fruits per plant were also collected in the summer rainfall region of the Eastern Cape in November 1992 but were not available at the other Eastern Cape sites. Problems were also experienced in obtaining fruit samples from the summer rainfall region of Kwazulu - Natal, Mpumulanga and the northern Province. In October 1992, two samples were collected at the Tendele site and six samples at the Giants Castle site. In March 1992, five samples (one of only 14 fruits and one of only 9 fruits) were collected at the Paradise Camp site, five samples

were collected at the Pilgrims Rest site and five samples from the Kaapse Hoop site although one of these was damaged by *Z. snelleni*. The study sites mentioned in the above text are listed in Chapter 2.

Damage levels attributable to *Z. snelleni* were considerable but were beyond the scope of this study.

## Results and Discussion

### *Eurytoma* sp.

The considerable variation in size between individuals of *Eurytoma* sp. indicated that more than one species may have been represented in the samples. However, an analysis of the variation of fifteen sets of measurements, which included characters of the head and antennae, thorax, fore wing, abdomen and male genitalia, found no fixed pattern of variation within and between samples and indicated that a single species is represented (Neser and Prinsloo 1995). An identification to species level was not feasible, but the species reared from Asparagaceae species is similar to *Eurytoma aloineae* (Burks), a Eurytomid associated with seeds of Aloes (Hyacinthaceae) (Neser and Prinsloo 1995).

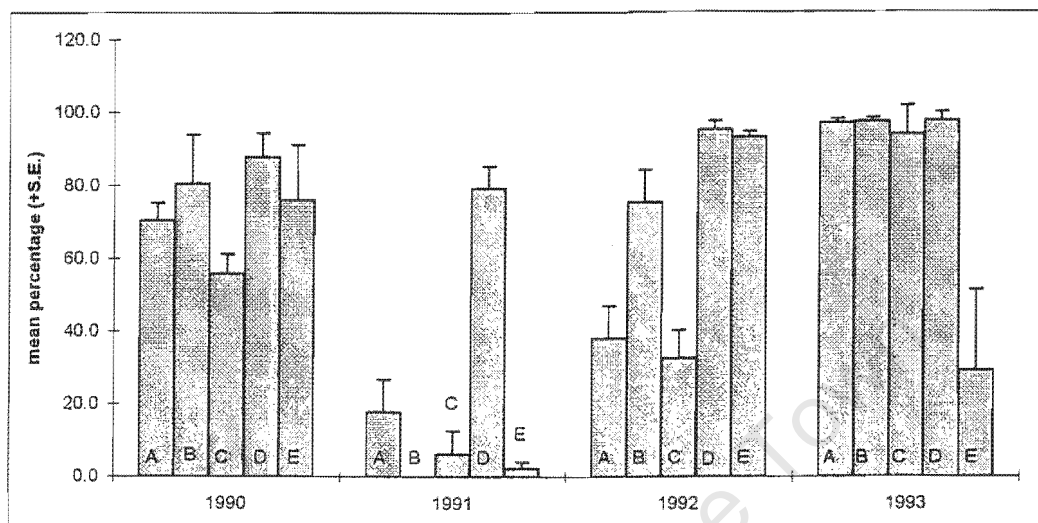
Damage levels achieved by *Eurytoma* sp. in the a-seasonal rainfall region of the Western Cape are presented in Table 4.1 and Fig. 4.1. On occasion it proved impossible to find a sample of 20 fruits from a single bridal creeper plant or otherwise the samples were badly damaged by the larvae of *Z. snelleni*. Consequently some samples consisted of fewer than 20 fruits. The number of fruits in the samples analysed for levels of damage attributable to *Eurytoma* sp. are listed in Table 4.1.

In November 1990 the percentage damage to seeds attributable to *Eurytoma* sp ranged between 55.8% ( $\pm 12.1$  S.D.) and 88.0% ( $\pm 14.0$  S.D.). The following fruiting season was characterised by low availability of seed and damage levels attributable to *Eurytoma* sp. were considerably lower except at Phantom Pass where a mean damage level of 79.4% ( $\pm 13.4$  S.D.) was measured. Mean damage levels at the other sites varied between 0 and 17.9% ( $\pm 19.8$  S.D.). In 1992 damage levels, at all sites, were higher than in 1991 and ranged between 32.6% ( $\pm 17.5$  S.D.) and 95.21% ( $\pm 5.1$  S.D.). This upward trend continued in 1993 at all sites, except Kaaimans River mouth, where damage levels of 29.2% ( $\pm 44.4$  S.D.) were measured. Damage levels varied between 94.0% ( $\pm 3.0$  S.D.) and 97.7% ( $\pm 5.2$  S.D.) at the remaining sites. During the 1993 season *Z. snelleni* was particularly prevalent at Kaaimans River Mouth and the abundance of this species may have reduced availability of fruit for *Eurytoma* sp. accounting for the lower levels of damage recorded.

**Table 4.1:** Mean percentage seed damage attributable to *Eurytoma* sp. associated with the widespread form of *A. asparagoides* in the a-seasonal rainfall region of the Western Cape.

	Mean percentage damage	Standard Deviation	No. of samples (no. fruits/sample)
<b>1990</b>			
Brenton Lake	70.4	11.0	5 (5x20)
Lake Pleasant	80.5	29.9	5 (5x20)
Sedgefield	55.8	12.1	5 (5x20)
Phantom Pass	88.0	14.0	5 (5x20)
Kaaimans River Mouth	75.9	34.0	5 (5x20)
<b>1991</b>			
Brenton Lake	17.9	19.8	5 (3x20, 19, 15)
Lake Pleasant	0.0	0.0	5 (5x20)
Sedgefield	6.3	14.1	5 (4x20, 18)
Phantom Pass	79.4	13.4	5 (4x20, 17)
Kaaimans River Mouth	2.4	5.4	5 (5x20)
<b>1992</b>			
Brenton Lake	38.1	19.7	5 (5x20)
Lake Pleasant	75.5	19.9	5 (5x20)
Sedgefield	32.6	17.5	5 (5x20)
Phantom Pass	95.2	5.1	5 (5x20)
Kaaimans River Mouth	93.1	3.7	5 (4x20, 18)
<b>1993</b>			
Brenton Lake	97.0	2.1	5 (3x20, 2x18)
Lake Pleasant	97.4	2.4	5 (4x20, 13)
Sedgefield	94.0	3.8	5 (4x20, 19)
Phantom Pass	97.7	5.2	5 (5x20)
Kaaimans River Mouth	29.2	44.4	4 (2x20, 18, 13)

Fig. 4.1: Mean ( $\pm$  S.E.) percentage damage to potentially viable seed of the widespread form of *Asparagus asparagoides*, in the a-seasonal rainfall region of the Western Cape, caused by *Eurytoma* sp. (A= Brenton Lake, B= Lake Pleasant, C= Sedgfield, D= Phantom Pass, E= Kaaimans River Mouth)



Efforts were made to analyse the levels of damage attributable to *Eurytoma* sp. in the winter rainfall region of the Western Cape during the 1993 fruiting season. However, fruit availability was limited and it was only possible to collect samples from the Nachtwacht and Swellendam sites, samples of fruit collected at the Nachtwacht site in October 1992 were also analysed. The number of fruits obtained per sample and the levels of damage are presented in Table 4.2. Damage levels at the Nachtwacht site were 69.9% ( $\pm$  21.1 S.D.) in 1992 and 83.4% ( $\pm$  14.9 S.D.) in 1993. At the Swellendam site damage levels of 92.0% ( $\pm$  6.4 S.D.) were recorded in the 1993 fruiting season. The high levels of damage recorded in this region illustrate the ability of *Eurytoma* sp. to establish high population levels in winter rainfall regions. This is an important consideration as most of the bridal creeper infested areas in Australia occur in winter rainfall regions.

A few fruit samples were obtained from the summer rainfall regions of southern Africa. The damage measured for these samples are presented in Table 4.2. At several of the sites no emergence of *Eurytoma* sp. was recorded (i.e. Paradise camp, Pilgrims Rest and Kaapse Hoop sites). However, six samples collected from the Giants Castle site revealed mean damage levels of 95.9% ( $\pm$  4.0 S.D.) and two samples from Tendele had an average damage of 52.7 % attributable to *Eurytoma* sp. Four samples of fruit collected at Cannon Rocks site in the summer rainfall region of the Eastern Cape showed a mean damage of 63.0% ( $\pm$  22.6 S.D.). These findings demonstrate the ability of *Eurytoma* sp. to survive and establish high population levels in regions characterised by summer rainfall and cold dry winters.

The distribution of *Eurytoma* sp. associated with *A. asparagoides* is given in Fig. 4.2. It occurs throughout the range of the widespread form of *A. asparagoides* in South Africa in all rainfall regions. In addition records from other *Asparagus* (previously *Myrsiphyllum*) species (Fig. 4.2) illustrate its ability to establish populations in the more arid West coast region of South Africa.

The biology of *Eurytoma* sp. associated with bridal creeper was superficially investigated. Adult females were observed probing green fruits with their ovipositors and dissections of these fruits revealed that they only probed fruit with seeds which still had a soft endocarp (Arne Witt pers. comm.). The egg is colourless and smooth. Dissections of seeds showed that usually only a single larva develops per seed, in rare circumstances two larvae were found but usually one of these was dead. During dissections of fruit from the a-seasonal rainfall region of the Western Cape in 1993, one seed containing two pupae was found.

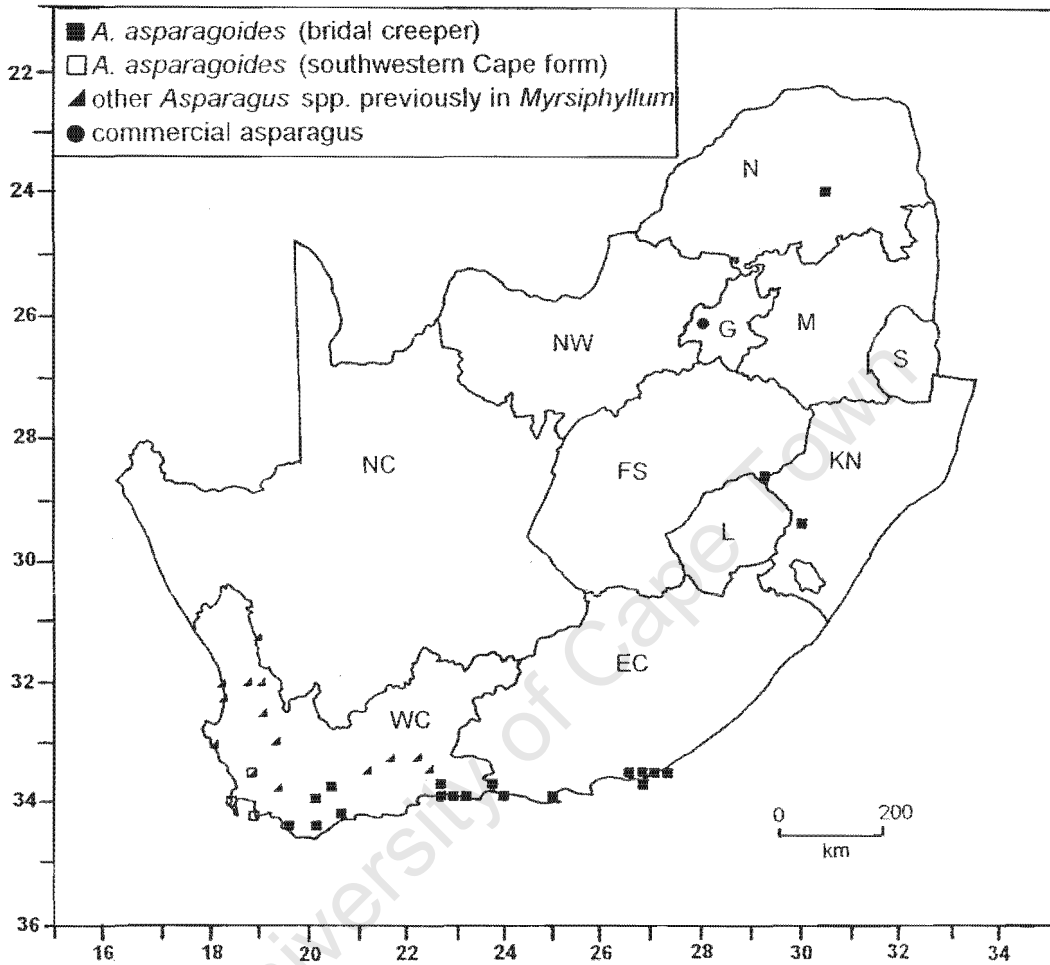
The impact of parasitism on population levels of *Eurytoma* sp. associated with bridal creeper was not specifically measured. However, the number of parasites reared from samples was extremely low. In an analysis of the insects reared from 68 samples collected from various localities (Appendix 4) four different species of Hymenopteran parasite were noted overall.

**Table 4.2:** Mean percentage seed damage attributable to *Eurytoma* sp. associated with the widespread form of *A. asparagoides* in (a) the winter rainfall region of the Western Cape, (b) at one site within the a-seasonal rainfall region of the Eastern Cape and (c) in the summer rainfall region (Drakensberg mountain range).

(grid references for the localities below are listed in Chapter 2)

	Mean percentage damage	Standard Deviation	No. of samples (no. fruits/sample)
<b>(a) winter rainfall region</b> (Western Cape)			
Nachtwacht - 22/10/1992	69.9	21.1	5 (19, 20, 20, 20, 20)
Nachtwacht - 08/09/1993	83.4	14.9	5 (20, 20, 20, 16, 20)
Swellendam - 07/09/1993	92.0	6.4	4 (20, 20, 20, 17)
<b>(b) a-seasonal rainfall region</b> (Eastern Cape)			
Cannon Rocks - 19/11/92	63.0	22.6	5 (20, 20, 11, 15, 20)
<b>(c) summer rainfall region</b> (Drakensberg mountain range)			
Tendele - 23/10/1992	52.7	12.7	2 (20, 20)
Paradise Camp - 15/02/1991	0.0	0.0	1 (19)
Paradise Camp - 23/03/1992	0.0	0.0	5 (20, 20, 20, 14, 9)
Pilgrims Rest - 23/03/1992	0.0	0.0	5 (20, 20, 20, 20, 19)
Kaapse Hoop - 24/03/1992	0.0	0.0	5 (20, 20, 20, 18, 20)
Giant's Castle 22/10/1992	95.9	4.0	6 (20, 20, 20, 19, 20, 20)

**Fig 4.2:** The distribution of *Eurytoma* sp. on the widespread and south-western Cape forms of *Asparagus asparagoides* in South Africa. Records from other *Asparagus* spp. previously in *Myrsiphyllum* are also shown. (WC = Western Cape, NC = Northern Cape, EC = Eastern Cape, FS = Free State, NW = Northwest, N = Northern Province, G = Gauteng, M = Mpumalanga, KN = Kwazulu-Natal, L = Lesotho, S = Swaziland.)



Relative to a total of 3292 *Eurytoma* sp. adults that emerged only 22 parasite individuals emerged, representing a percentage parasitism of less than 1%. For the purposes of the analysis all parasite individuals were regarded as having emerged from an individual *Eurytoma* sp. although parasite species 1 is probably gregarious. As samples were removed from the field, they were protected from further parasitism and consequently the results present an under-representation of the levels of parasitism, nonetheless, the results indicate that parasitism levels are low in southern Africa.

### ***Zalaca snelleni***

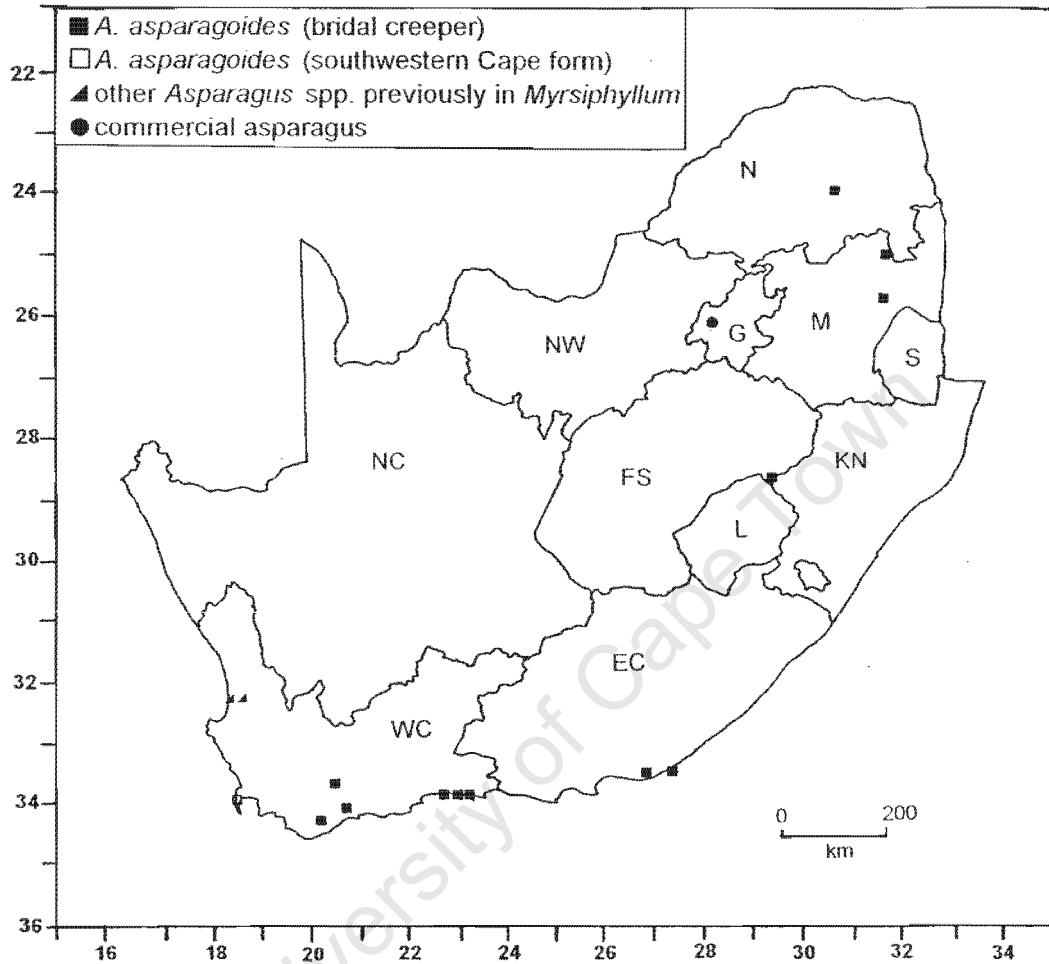
*Zalaca snelleni* was reared from both forms of *A. asparagoides* and also from *A. declinatus* L. and *A. ovatus* (two species that were previously placed in the genus *Myrsiphyllum*), it was also reared from commercial asparagus (Appendix 4). In addition, *Z. snelleni* was reared from several *Asparagus* species previously in the genus *Protasparagus*. The distribution of *Z. snelleni* in South Africa is given in Fig. 4.3. Damage levels attributable to *Z. snelleni* were not measured but indications are that they are capable of causing considerable damage. Each larva consumes the contents of several fruits, including the seeds, during its development. The larvae enter a fruit and then spin a concealing web over the entrance point, they eat the contents of the fruit, leaving the surface intact. When the contents are exhausted the larvae move and enter another fruit. Pupation occurs in a cocoon attached to the stem of the plant. The larvae are subject to parasitism by an unidentified species of Braconid wasp.

### **General Discussion**

*Eurytoma* sp. associated with bridal creeper in southern Africa is capable of surviving and of establishing high population levels in all the rainfall regions of southern Africa. If further studies reveal that the wasp is sufficiently specific for use in a biological control programme against bridal creeper in Australia, it has the potential to be extremely successful at reducing the spread of bridal creeper in Australia. The related, *Eurytoma attiva* Burks is regarded as a successful biological control agent in the control of *Cordia curassavica* (Jacquin) Roemer and Schultes (Ehretiaceae - black sage) in Malaysia and Mauritius (Julien 1992). Results from South Africa show that percentage damage to seeds is low when fruits are scarce but the populations of wasps recover within two years when fruit is readily available.

*Eurytoma* sp. was also reared from the fruit of commercial asparagus however, it is not recorded as a pest of this crop (Annecke and Moran 1982). Farmers do not use the seeds and find it useful to have the seeds destroyed to prevent self seeding within the lands (A. Witt, CSIRO, Cape Town, pers. comm.). Australian asparagus farmers will need to be consulted to assess the potential implication of the release of *Eurytoma* sp.

**Fig 4.3:** The distribution of *Zalaca snelleni* on both forms of *Asparagus asparagoides* in South Africa and on other *Asparagus* spp. previously in *Myrsiphyllum*. (WC = Western Cape, NC = Northern Cape, EC = Eastern Cape, FS = Free State, NW = Northwest, N = Northern Province, G = Gauteng, M = Mpumalanga, KN = Kwazulu-Natal, L = Lesotho, S = Swaziland.)



*Zalaca snelleni* has received very little attention to date. If *Eurytoma* sp. should prove to be unsuitable as a biological control agent against bridal creeper in Australia, the moth may warrant further investigation. *Zalaca snelleni* was often damaging to samples of fruit collected for *Eurytoma* sp. analyses and may conceivably be damaging to field populations of the wasp as it is probable that the larvae of *Z. snelleni* consume the larvae of *Eurytoma* sp. when eating the fruit contents.

University of Cape Town

## Chapter5

### Experimental analysis of the impact of *Zygina* sp. (Cicadellidae) on growth and reproduction of the widespread form of *Asparagus asparagoides*.

#### Introduction

Bridal creeper has an extensive tuber system and an organism directly attacking this system would be highly desirable for use in a biological control programme. However, extensive surveying did not reveal a candidate that meets this requirement. Extensive foliage damage caused by *Zygina* sp. (Cicadellidae) may impact significantly on tuber growth.

The experiment described below measured the impact, on reproductive output and tuber growth, of damage caused by *Zygina* sp. If foliage damage can reduce the rate of tuber production in bridal creeper thereby reducing vegetative spread then a suite of foliage attacking insects would be a suitable alternative to an organism that directly attacks the tuber system of the plant. If, the damage also impacts on fruiting capacity of the plant the long range dispersal of bridal creeper may also be reduced.

#### Methods

About 100 bridal creeper tuber masses were collected from a site being cleared for development at Brenton-on-Sea (34°04'S 23°02'E) on 09/11/1990. They were transported to Cape Town, washed and kept moist. On 13/11/1990 they were pruned, using secateurs, to a section of rhizome with a single growing tip and 15 tubers. Considerable variation was noted in the size of tubers, density of packing of tubers and the numbers of old versus new tubers (Fig. 5.1). The sections were planted the following day in numbered black plastic potting bags (Diameter 200mm, height 120mm) containing soil from a single batch which included river sand and potting mix. The bags were placed in a sheltered shady position and watered with mist irrigation when required. Re-growth was vigorous but varied considerably, total number of cladodes produced per plant was recorded after two months (January 1991). The plants were trained onto wire pyramid frames (500mm high) and prevented from becoming entangled with each other.

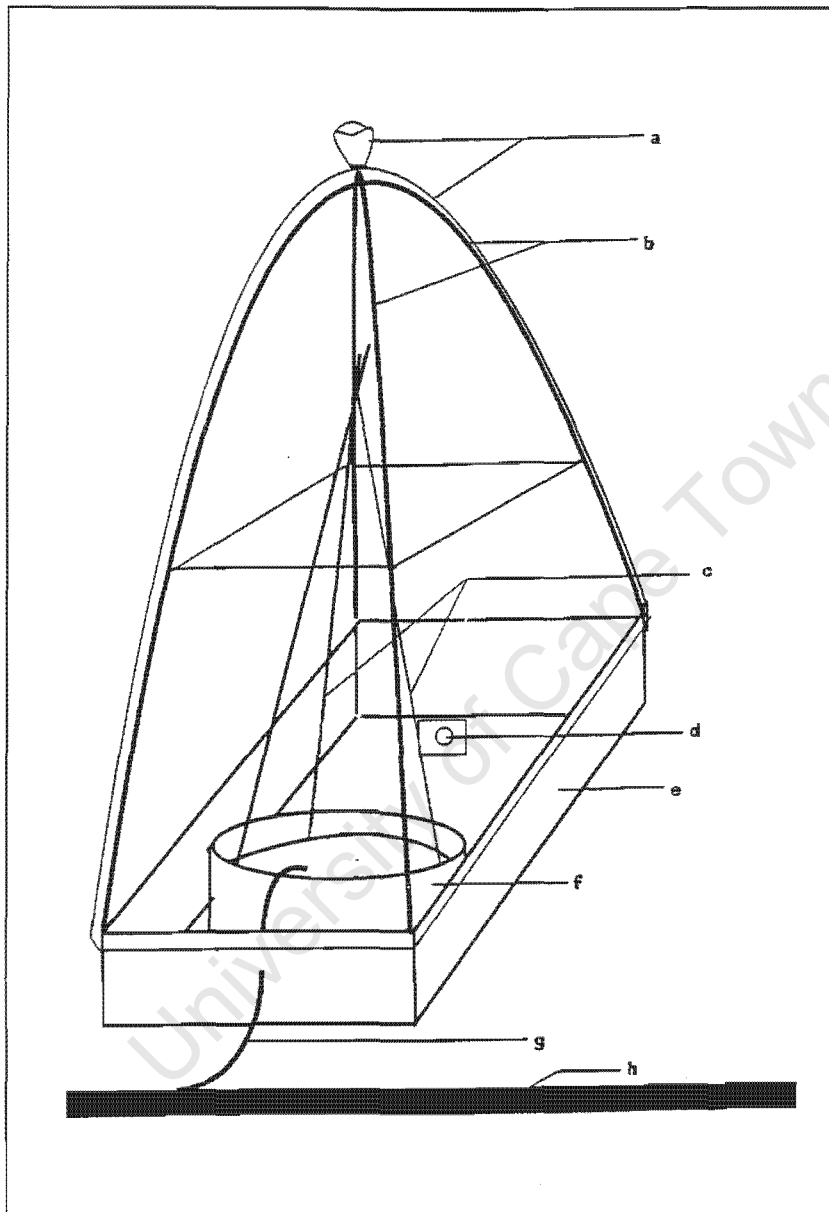
On 07/05/1991 (6 months growth) the plants were paired, based on the number of stems, the number of shoots at the base and a visual assessment of the amount of foliage, new growth and health. 36 well-matched pairs were allocated. On 22 June the 12 pairs that had retained the best match were selected for the experiment. All plants were sprayed with a non-residual insecticide (Trounce) and placed in insect proof cages (Fig. 5.2). After 24 hours all the plants were sprayed with water to remove the pesticide. A member of each pair was randomly

**Fig 5.1:** Sections of rhizome, with a single growing tip and 15 tubers, of the widespread form of *Asparagus asparagoides*, used in the experiment to note the effects of the impact of *Zygina* sp. (Cicadellidae) on growth and reproduction in this species.



University of

**Fig 5.2:** Illustration of the insect-proof cages constructed to exclude herbivores from control plants and to contain *Zygina* sp. on treatment plants while excluding other herbivores. (a= a sleeve of white muslin cloth attached to the base of the cage, supported by a wire frame and secured at the top of the cage with an elastic tie, b= wire supporting framework, c= wire tripod on which the bridal creeper plants were trained, d= drainage hole covered by gauze, e= plastic cage base, f= plant bag, g= drip feed irrigation tube, h= irrigation pipe)



allocated as a treatment plant (to be exposed to *Zygina* sp.) or control (kept free of *Zygina* sp. damage). Thirty *Zygina* sp. were released onto each treatment plant. The cages were randomly placed in a shade house and linked to a drip-feed irrigation system which provided water as required.

In October plants that were not included in the experiment were measured to determine whether a direct correlation exists between above ground and below ground growth. The above ground material was cut off, dried and weighed. The tubers were dug up, washed and weighed and the number of tubers was counted.

Bridal creeper self-fertilises. In November, fruit production of treatment versus control plants was assessed by counting the number of fruits produced on each plant. Possible contamination by *Zygina* sp. of control plants was prevented by opening and recording the details of control plants first. After assessment, the cages were re-sealed. In December 30 *Zygina* sp. were re-released onto each of the treatment plants.

The experiment was terminated approximately one year after it was initiated (April 1992). The following parameters were recorded:

- number of green stems
- number of dead stems
- estimate of amount of new growth (all experimental plants were allocated a code ranging between 1=very little new growth and 9=profuse new growth)
- estimate of amount of senescence (all experimental plants were allocated a code ranging between 1=very little senescence and 9=profuse senescence)
- estimate of overall health (all experimental plants were allocated a code ranging between 1=very poor health and 5=excellent health)
- estimate of level of *Zygina* sp. damage (all experimental plants were allocated a code ranging between 0=no *Zygina* sp. damage and 9=extensive *Zygina* sp. damage)
- the total number of tubers

Above ground growth was cut off, dried (for 48 hours at 85<sup>0</sup>C) and weighed on a Mettler PM 460 balance. The tubers were cut off the rhizome, dried (for 70 hours at 85<sup>0</sup>C) and weighed on the above balance. The rhizome was also dried (for 70 hours at 85<sup>0</sup>C) and weighed.

The results were analysed with paired Students t-tests.

## Results

Analysis of above ground versus below ground material of plants not used for the experiment revealed a direct linear correlation ( $r=0.834$ ) between above and below ground growth (Fig. 5.3). This validates the selection of pairs based on above ground similarities.

Fig. 5.3: Correlation between above and below ground mass of bridal creeper.  
(n=47) (r=0.83)

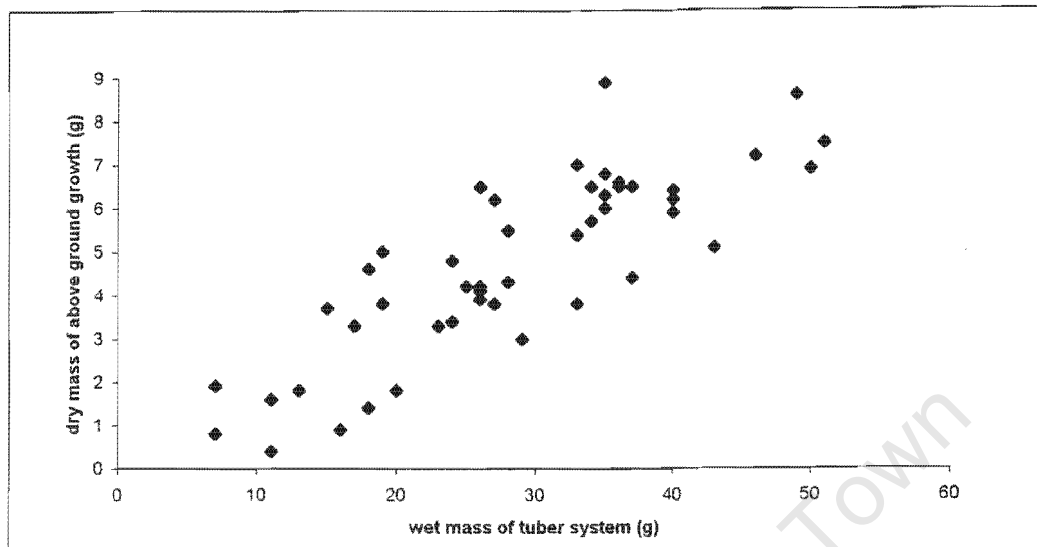
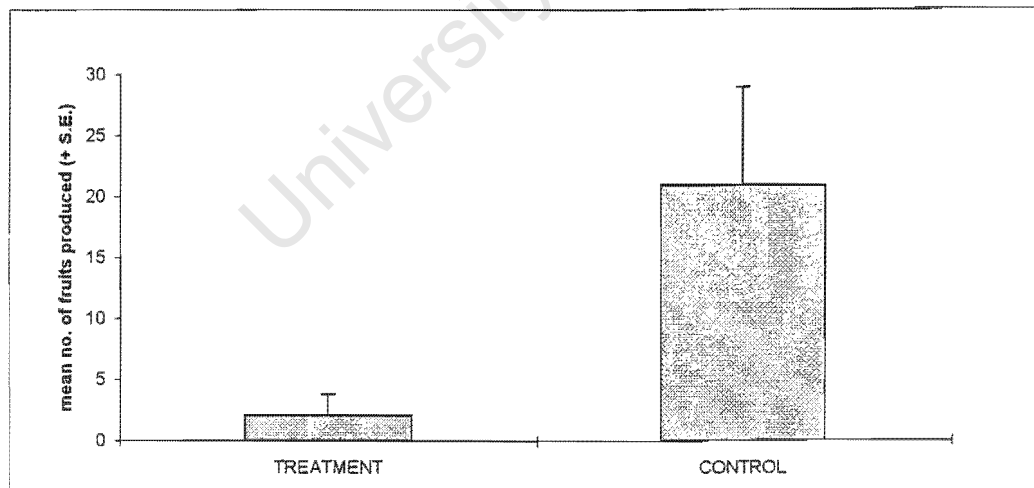


Fig 5.4: Impact of damage of the *Zygina* sp. (Cicadellidae) associated with bridal creeper on fruit production (November 1991)



Analysis of fruit production on treatment versus control plants showed that plants not exposed to *Zygina* sp. produced significantly more fruit (Table 5.1) and Fig. 5.4. Photographs of a control plant (Fig. 5.5a) and a treatment plant (Fig. 5.5b) provide a visual comparison which illustrates the dramatic differences.

Results from termination of the experiment are listed in Table 5.1 and are illustrated in Fig. 5.6a - f. Control and treatment plants did not have significantly different numbers of green stems, however, treatment plants had significantly more dead stems suggesting that *Zygina* sp. was causing death of stems which were then replaced by the plant (Fig. 5.6a). This premise is supported by the fact that 3 of the treatment plants had a new shoot at the base while no control plants were producing basal shoots at the time the experiment was terminated. Overall, the control plants had more new growth, less senescence and were healthier than treatment plants (Fig 5.6b). Throughout the course of the experiment plants were observed to ensure that treatment plants were subject to sustained *Zygina* sp. damage and that control plants remained free of insect damage. At the termination of the experiment the *Zygina* sp. damage to treatment plants was consistently high while only a single control plant showed a minute amount of damage (Table 5.1).

The total tuber dry mass of control plants was significantly higher than for treatment plants (Fig 5.6c). However, the total number of tubers was not significantly different (Fig. 5.6d). Analysis of the mean weight of tubers showed that the tubers of control plants were significantly heavier than those of treatment plants (fig. 5.6 (e)) showing that bridal creeper responds to stress by producing smaller rather than significantly fewer tubers. The dry mass of the rhizome in control plants was significantly heavier than in treatment plants (fig. 5.6 (f)) and, the total above ground mass was similarly significantly more for control plants (Fig.5.6d).

## Discussion

The presence of *Zygina* sp. impacts negatively on fruit production in bridal creeper thereby making this a potentially useful agent for reducing the spread by seed of bridal creeper. In the absence of a suitable agent to directly attack the tuber system use of *Zygina* sp. or other foliage feeding organisms could also be expected to significantly reduce vegetative spread of bridal creeper if significant population levels are reached. Fruit production presumably impacts negatively on tuber reserves and as the control plants produced significantly more fruit, in the absence of fruiting, the difference between tuber production in treatment and control plants may have been even more significant. No mortality of plants was recorded during the course of the experiment. Although treatment plants performed less well than control plants with respect to both fruit and tuber production, the mass of tubers at the time that the experiment started (i.e. six months had elapsed since planting of the tubers) is not

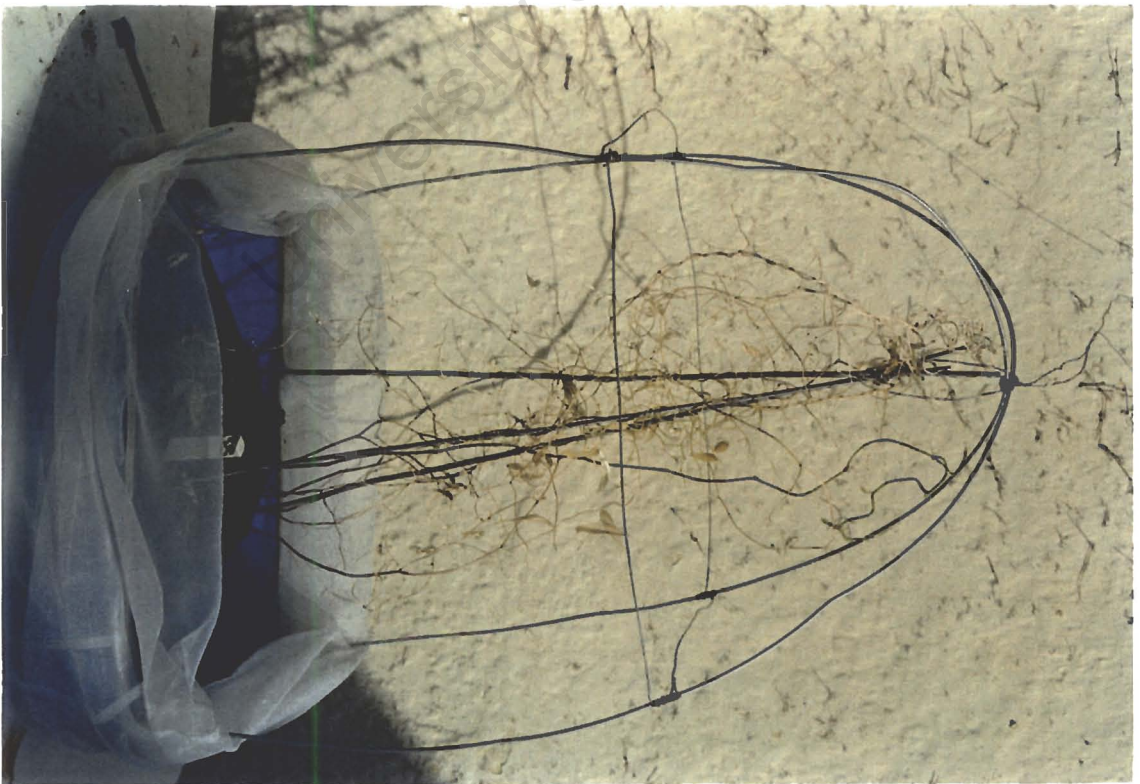
Fig 5.5: (a) Control plant on analysis of fruiting versus, overleaf (b) treatment plant on the same occasion.

(a)



Fig 5.5 (cont.): (b) treatment plant on analysis of fruiting.

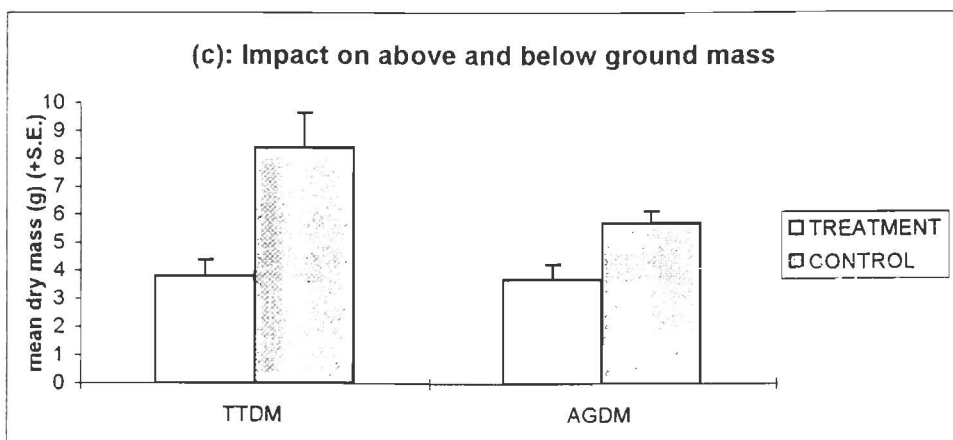
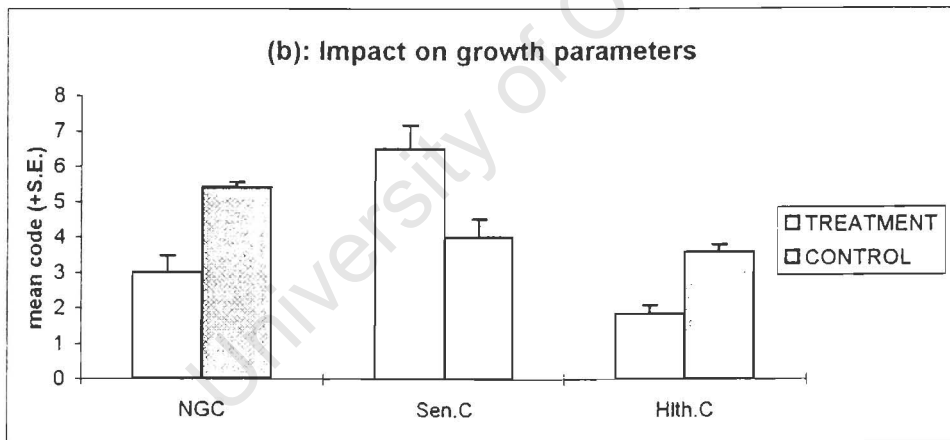
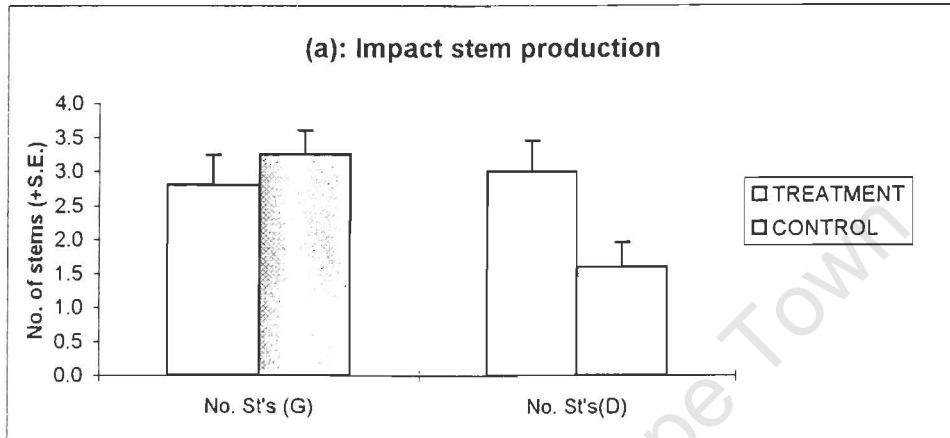
(b)



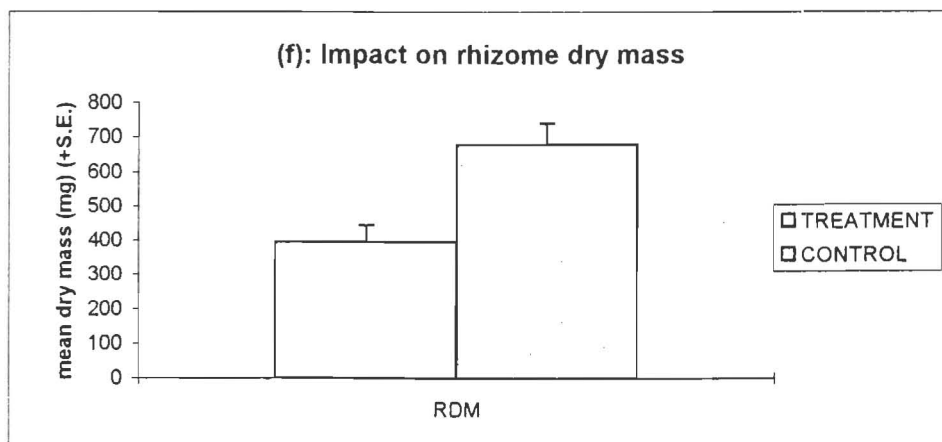
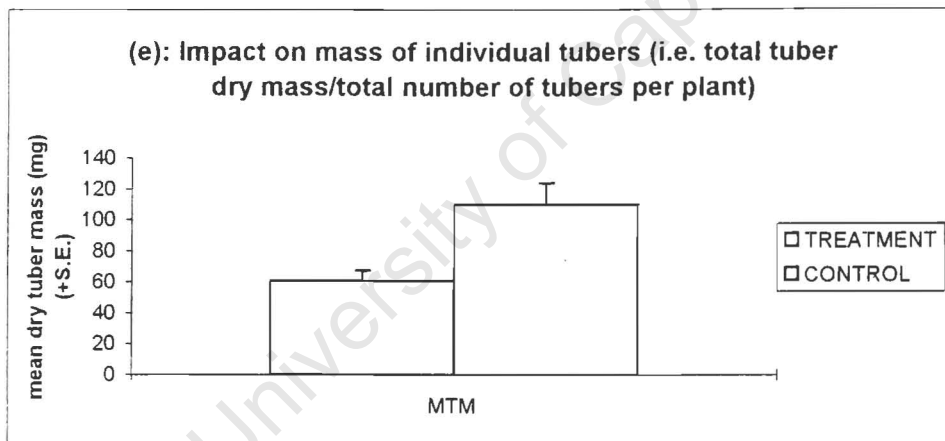
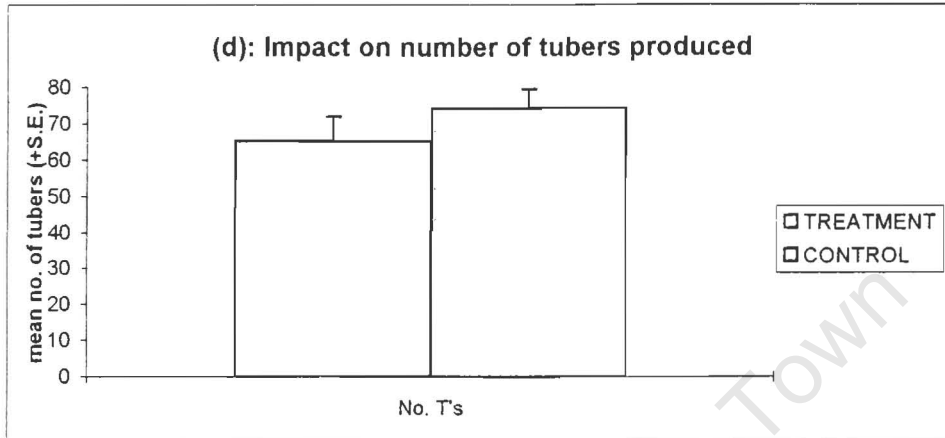
**TABLE 5.1:** Impact of *Zygina* sp. (Cicadellidae) associated with bridal creeper on fruit production (recorded in November 1991) and on growth parameters (measured in April 1992 on termination of the experiment) under experimental conditions.

	Treatment	Control	Treatment		Control		Students T-test	
	range	range	mean	St. Dev.	mean	St. Dev.	P	
No. OF GREEN STEMS	1-6	1-5	<b>2.8</b>	1.53	<b>3.3</b>	1.22	0.435	NS
No. OF DEAD STEMS	1-6	1-5	<b>3.0</b>	1.60	<b>1.6</b>	1.24	0.024	<b>SIGN.</b>
CODE FOR NEW GROWTH (Code 1=v.little 9=lots)	1-5	5-6	<b>3.0</b>	1.62	<b>5.4</b>	0.52		
CODE FOR SENESCENCE (Code 1=v.little 9=lots)	3-9	1-7	<b>6.5</b>	2.28	<b>4.0</b>	1.76		
CODE FOR HEALTH (Code 1=v.poor 5=v.good)	1-3	3-5	<b>1.8</b>	0.84	<b>3.6</b>	0.67		
CODE FOR <i>Zygina</i> sp. DAMAGE (Code 1=v.little 9=lots)	5-9	0-1	<b>7.7</b>	1.67	<b>0.1</b>			
TOTAL No. TUBERS	27-112	42-93	<b>65.2</b>	23.13	<b>74.2</b>	18.44	0.109	NS
TUBER DRY MASS (g)	0.98 - 6.72	2.74 - 15.79	<b>3.8</b>	2.00	<b>8.4</b>	4.25	0.003	<b>SIGN.</b>
MEAN TUBER WEIGHT (mg)	36 - 99	59 - 216	<b>61</b>	24	<b>110</b>	48	0.011	<b>SIGN.</b>
RHIZOME DRY MASS (mg)	214 - 631	426 - 1102	<b>397</b>	167	<b>680</b>	212	0.003	<b>SIGN.</b>
DRY ABOVE GROUND GREEN MASS (g)	1.19-6.40	3.86-8.05	<b>3.7</b>	1.87	<b>5.7</b>	1.40	0.014	<b>SIGN.</b>
No. OF FRUITS PRODUCED	0-20	0-98	<b>2.08</b>	5.823	<b>21</b>	27.687	0.036	<b>SIGN.</b>

**Fig 5.6:** Results on termination of the experiment examining the impact of sustained *Zyginia* sp. damage on various plant growth parameters of bridal creeper (a) impact on stem production, (b) impact on new growth, senescence and health, (c) impact on above and below ground mass, (d) impact on number of tubers produced, (e) impact on the mass of individual tubers, (f) impact on the mass of the rhizome. (key: No. St's (G)= number of green stems, No. St's (D)= number of dead stems, NGC= new growth code, Sen. C= senescence code, Hlth. C= health code, No. T's= number of tubers, TTDM= total tuber dry mass, AGDM= above ground dry mass, MTM= mean mass of individual tubers, RDM= rhizome dry mass)



**Fig 5.6 (cont):** Results on termination of the experiment examining the impact of sustained Cicadellid damage on various plant growth parameters of bridal creeper. (key: No. St's (G)= number of green stems, No. St's (D)= number of dead stems, NGC= new growth code, Sen. C= senescence code, Hlth. C= health code, No. T's= number of tubers, TTDM= total tuber dry mass, AGDM= above ground dry mass, MTM= mean mass of individual tubers, RDM= rhizome dry mass)



known and hence it is not known whether *Zygina* sp. attack caused reduced tuber production or actually resulted in a reduction of tuber reserves. Under caged circumstances extremely high levels of damage were achieved. However, *Zygina* sp. have also been noted to reach extremely damaging levels in the field in certain years. The factors which impact most significantly on population levels of *Zygina* sp. under field conditions were not investigated during this study. However, as levels were high at all sites in the a-seasonal rainfall region of the Western Cape simultaneously, it seems likely that environmental factors were responsible.

One of the primary problems with control of bridal creeper, in the absence of a potential agent for use against the tuber system directly, is the extensive underground reserves that it produces which enable successive regeneration after damage to above ground growth. A similar problem exists with the control of Canada thistle which reproduces primarily vegetatively and for which no suitable organism was found for below ground attack (Ang et.al. 1995). These authors showed that use of foliage attacking organisms significantly reduced both biomass and survival of the thistle and that this effect was increased when other stresses (competition and water stress) were present. Sustained attack by foliage attacking organisms may similarly be expected to have a marked effect on populations of bridal creeper.

## Synopsis

At the inception of this project to establish the feasibility for the potential for biological control of bridal creeper a recent revision of *Asparagus asparagoides* and related species had been undertaken. During the course of the study it became apparent that this revision was deficient in certain aspects. Most significantly, the study illustrated that the documented distribution of *A. asparagoides* was misleading in several aspects, and that the distribution of bridal creeper though widespread in southern Africa was considerably more restricted than presented in the documented literature. In addition, this study, demonstrated the presence two forms of *A. asparagoides* (sensu Obermeyer 1984) and showed that only the widespread form of *A. asparagoides* occurs in Australia. The potential range of bridal creeper in Australia is considerable as the plant occurs in all three rainfall regions in South Africa. At present, bridal creeper in Australia is restricted primarily to winter rainfall regions.

The list of potential agents for use against bridal creeper in Australia was found to be limited and unfortunately did not include an organism that attacks the tuber system of the plant directly. Experimental results illustrated however, that, organisms that attack the foliage of the plant, have the potential to reduce fruit production and impact negatively on the tuber system. Potential agents, subject to further investigation include three species that attack the foliage and stems of bridal creeper, a *Zygina* sp. (Cicadellidae), the rust fungus (*Puccinia myrsiphyllii*) and a Chrysomelid beetle, *Crioceris* sp. (Criocerinae) that is related to a pest of commercial Asparagus, *A. officinalis*. The *Zygina* sp. has now been released in Australia. In addition, a *Eurytoma* sp. that attacks the seeds of bridal creeper and was shown to have consistently high levels of damage is under consideration as a potential agent. The *Eurytoma* sp. has been imported into quarantine in Australia and specificity testing is being undertaken (P. Müller, CSIRO Biological Control Unit, University of Cape Town, pers. comm).

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**APPENDIX 1: Confirmed distribution of both forms of *Asparagus asparagoides* in southern Africa**

(Voucher specimens from CSIRO surveys were allocated an Accession No. (prefixed AcCSIRO) and are housed in the Bolus Herbarium of the University of Cape Town)

**WIDESPREAD FORM OF *ASPARAGUS ASPARAGOIDES* (BRIDAL CREEPER)**

SOURCE	ACCESSION No.	QUARTER DEGREE SQUARE	LOCALITY	PROVINCE
PRE		3128AA	Umtata, N of Ugie	Eastern Cape
CSIRO survey	AcCSIRO 108	3326CB	Alexandria Forest	Eastern Cape
PRE		3326CB	Alexandria Forest	Eastern Cape
CSIRO survey	AcCSIRO 042	3326DA	8km from Southwell junction	Eastern Cape
CSIRO survey		3326DA	Moneysworth Farm	Eastern Cape
CSIRO survey	AcCSIRO 043, 107	3326DA	Southwell	Eastern Cape
CSIRO survey	AcCSIRO 044, 045	3326DB	Jones Farm (5km E of Bathurst)	Eastern Cape
CSIRO survey		3326DB	near Bathurst on route Kleinemonde	Eastern Cape
CSIRO survey		3326DC	Cannon Rocks	Eastern Cape
CSIRO survey	AcCSIRO 040, 041	3327CA	Fish River Mouth	Eastern Cape
PRE		3327CA	Kleinemonde	Eastern Cape
Compton Herbarium, Kirstenbosch		3327CA	Kleinemonde	Eastern Cape
CSIRO survey	AcCSIRO 046	3327CA	nr. Kleinemonde	Eastern Cape
CSIRO survey		3423BB	Tsitsikama National Park, Storms River Mouth	Eastern Cape
CSIRO survey		3424BB	St Francis Bay	Eastern Cape
PRE			Kentani	Eastern Cape
CSIRO survey			Van Stadens River Mouth, near campsite	Eastern Cape
PRE		2627AD	A. Bailey Nature Reserve, Carltonville	Gauteng
PRE		2730AD	Oshoek Farm	Kwazulu Natal
CSIRO survey	AcCSIRO 101, - 102	2731CD	Ngome Plateau	Kwazulu Natal
CSIRO survey	AcCSIRO 048, 055	2828DB	Tendele, Royal Natal National Park	Kwazulu Natal
PRE		2929AB	Giants Castle, main caves area	Kwazulu Natal
CSIRO survey	AcCSIRO 050, 054	2929BC	Giants Castle Game Reserve (at rest camp)	Kwazulu Natal
CSIRO survey	AcCSIRO 049, 053	2929CA	Drakensberg Garden Hotel environs	Kwazulu Natal
CSIRO survey		2929DA	12km East of Loteni on route Giants Castle	Kwazulu Natal
CSIRO survey	AcCSIRO 051	2930CA	9km before Ncwadi siding on Richmond Bulwer Rd.	Kwazulu Natal
CSIRO survey	AcCSIRO 052	2930CA	Byrne Valley	Kwazulu Natal
CSIRO survey		2930CA	Hella Hella at base alongside river	Kwazulu Natal
PRE		2930CC	Byrne	Kwazulu Natal
CSIRO survey		3030AA	7km after Hella Hella junction approaching from the South	Kwazulu Natal
CSIRO survey	AcCSIRO 047	3030AA	Elliogarty Farm, 7km after Richmond Junction (about 17km NW of Ixopo)	Kwazulu Natal
PRE		2828CC	Leribe	Lesotho
CSIRO survey	AcCSIRO 064	2430DD	Paradise Camp resort near gods Window	Mpumalanga
CSIRO survey	AcCSIRO 058, 061	2430DD	Stanley Bush Kop near Pilgrims Rest	Mpumalanga
PRE		2530AA	Oshoek Farm Draaikraal	Mpumalanga

APPENDIX 1 (Cont.) : Confirmed distribution of both forms of *Asparagus asparagoides* in southern Africa.

WIDESPREAD FORM OF *ASPARAGUS ASPARAGOIDES* (BRIDAL CREEPER) - continued

SOURCE	ACCESSION No.	QUARTER DEGREE SQUARE	LOCALITY	PROVINCE
CSIRO survey		2530BB	Bridal Veil Falls (Ceylon State Forest)	Mpumalanga
CSIRO survey	AcCSIRO 056, 059	2530DB	Kaapse Hoop Plateau	Mpumalanga
PRE		2531AD	Malelaneberg area, Kruger National Park	Mpumalanga
CSIRO survey		2531CC	Barberton	Mpumalanga
CSIRO survey	AcCSIRO 063	2531CC	On route Pigg's Peak (Barberton vicinity)	Mpumalanga
CSIRO survey	AcCSIRO 057, 062, 065	2527CD	Breedtsnek Magaliesberg	North West
CSIRO survey	AcCSIRO 060	2329DD	Kromdraai Farm near Magoebaskloof	Northern Transvaal
PRE		2330CC	Woodbush	Northern Transvaal
Compton Herbarium, Kirstenbosch		2829AC	Kings Hill adjoining Botanic Garden, Harrismith town lands	Orange Free State
PRE			Thabaneng	prob. Lesotho
CSIRO survey	AcCSIRO 164	3319DD	Pat Busch Nature Reserve near Robertson	Western Cape
CSIRO survey	AcCSIRO 106	3320CC	Cogmans Kloof, Mr Conradies Farm	Western Cape
PRE		3320CC	Mr Conradies farm, Cogmans Kloof, Montagu	Western Cape
CSIRO survey		3320CD	18km West of Swellendam, Joubertsdal farm	Western Cape
CSIRO survey	AcCSIRO 011	3322DC	Old George/Knysna Rd	Western Cape
PRE		3322DC	Saasveld	Western Cape
CSIRO survey	AcCSIRO 103	3419BC	Hillside Farm, 20 km from Caledon on route Napier	Western Cape
CSIRO survey	AcCSIRO 148	3419DA	Awoka Farm, 15 km NE of Gansbaai	Western Cape
CSIRO survey	AcCSIRO 160	3419DB	Elim Village	Western Cape
CSIRO survey	AcCSIRO 156	3419DB	Haze-Vlakte Farm, 22 km w of Bredasdorp on route Elim	Western Cape
CSIRO survey		3420AA	3.5km beyond Stormsvlei on route Bonnievale	Western Cape
CSIRO survey		3420AB	6.5km West of Swellendam, Skoongesig Farm	Western Cape
CSIRO survey		3420BA	Niekerkshek siding, 25 km West of Swellendam	Western Cape
CSIRO survey		3420BC	Buffelsfontein	Western Cape
CSIRO survey	AcCSIRO 018, 022, 104, 115, 149	3420BC	Potberg Mountain	Western Cape
CSIRO survey	AcCSIRO 175	3420BD	Kontiki Farm, on route Infanta	Western Cape
CSIRO survey	AcCSIRO 017	3420CA	Nachtwacht Farm, 8km S of Bredasdorp	Western Cape
CSIRO survey	AcCSIRO 013, 105	3421AA	Kweekkraal Farm on N2 W of Riversdale	Western Cape
PRE		3421AA	Kweekkraal, Riversdale	Western Cape
PRE		3421AB	Riversdale	Western Cape
CSIRO survey	AcCSIRO 168	3421AD	Stilbaai West	Western Cape
CSIRO survey	AcCSIRO 169	3421BB	1.4km from junction N2 with secondary road to Gouritzriver (near Cooper siding)	Western Cape
CSIRO survey	AcCSIRO 174	3421BD	near bridge over Gouritzriver at Johnsons Post	Western Cape
CSIRO survey		3422AA	Mosselbay	Western Cape
CSIRO survey	AcCSIRO 021	3422BA	Kaaimans River Mouth, nr. Wilderness	Western Cape
CSIRO survey		3422BB	Sedgefield	Western Cape
CSIRO survey	AcCSIRO 016. 020	3423AA	At base of Phantom Pass nr. Knysna	Western Cape

APPENDIX 1 (Cont.) : Confirmed distribution of both forms of *Asparagus asparagoides* in southern Africa.

WIDESPREAD FORM OF *ASPARAGUS ASPARAGOIDES* (BRIDAL CREEPER) - continued

SOURCE	ACCESSION No.	QUARTER DEGREE SQUARE	LOCALITY	PROVINCE
CSIRO survey	AcCSIRO 014, 015	3423AA	Brenton-on-Sea	Western Cape
CSIRO survey	AcCSIRO 012	3423AA	Knysna (on pathway to the heads)	Western Cape
PRE		3423AA	Noetsi River	Western Cape
PRE			Hopewell, Bathurst division	Western Cape
PRE		2527DD	Uitkomst, Skeerpoort River, Rustenberg District	
PRE			Clarence	

SOUTH-WESTERN CAPE FORM OF *ASPARAGUS ASPARAGOIDES*

SOURCE	ACCESSION No.	QUARTER DEGREE SQUARE	LOCALITY	PROVINCE
CSIRO survey	AcCSIRO 163	3318CD	Rhodes Memorial, Cape Town	Western Cape
CSIRO survey	AcCSIRO 165, 166	3318DB	Paarl Rock	Western Cape
CSIRO survey	AcCSIRO 161	3418AB	4km NW of Scarborough	Western Cape
Compton Herbarium, Kirstenbosch		3418AB	Bergvliet Farm, Constantia	Western Cape
CSIRO survey		3418AB	Karbonkelberg	Western Cape
CSIRO survey		3418AB	Olifantsbaai (Cape Point Nature Reserve)	Western Cape
CSIRO survey		3418AB	Princess Vlei	Western Cape
CSIRO survey		3418AB	Red Hill	Western Cape
CSIRO survey		3418AB	Silvermine	Western Cape
CSIRO survey	AcCSIRO 024, 026	3418AB	Silvermine Nature Reserve, Cape Peninsula	Western Cape
CSIRO survey		3418AB	West Lake golf Coarse	Western Cape
CSIRO survey		3418BD	Hangklip Rd near Bettys bay	Western Cape
CSIRO survey		3418BD	Sea Farm (nr. Betty's Bay)	Western Cape
CSIRO survey	AcCSIRO 025	3419CB	nr. Franskraal Farm (Gansbaai vicinity)	Western Cape
CSIRO survey		3420AD	De Hoop Vlei, De Hoop Nature Reserve	Western Cape
CSIRO survey	AcCSIRO 159	3420BC	Koppie Alleen, De Hoop Nature Reserve, Bredasdorp District	Western Cape
CSIRO survey	AcCSIRO 170	3421AC	4km from Vermaaklikheid junction (on route Vermaaklikheid from Stilbaai)	Western Cape
CSIRO survey		3421AD	1km North East of Jongensfontein Settlement	Western Cape
CSIRO survey	AcCSIRO 167	3421AD	Blikhuis farm (10km from Stilbaai on route Gouritzmond)	Western Cape
CSIRO survey	AcCSIRO 173	3421BC	Yzervarkfontein farm, 4km before Albertinia junction on route Stilbaai from Johnsons Post	Western Cape
PRE			eastern slopes Kalk Bay mountain	Western Cape
CSIRO survey			eastern slopes Kalk Bay mountain	Western Cape

**APPENDIX 2 :** CSIRO survey records of *Asparagus* (previously *Myrsiphyllum*) species used, in conjunction with the CSIRO records listed in Appendix 1, for the production of Fig. 3 to show the extent of the CSIRO survey for *Asparagus asparagoides*.

Specimens for which vouchers were collected have an accession number (prefixed AcCSIRO) and are lodged in the Bolus Herbarium of the University of Cape Town. The remaining records are derived from the CSIRO surveys but no voucher specimens were collected.

ACCESSION No.	QUARTER DEGREE SQUARE	DATE	LOCALITY
<b><i>Asparagus kraussianus</i></b>			
AcCSIRO 027	3419AB	14.06.1993	On route Genadendal
AcCSIRO 028	3420BC	15.06.1993	Potberg Mountain, De hoop Nature Reserve, Bredasdorp District
AcCSIRO029	3319CA	08.08.1992	Base of Baineskloof Pass nr. Wellington
AcCSIRO 030	3219CA	06.10.1992	33.5km from "Op die Berg" (Die Boom Farm)
AcCSIRO 031	3219CA	10.07.1990	14km from Citrusdal on route Ceres
AcCSIRO 032	3219CA	01.07.1990	14km from Citrusdal on route Ceres
AcCSIRO 033	3419AD	14.08.1992	Hermanus (on coast)
AcCSIRO 034	3218BB	07.10.1992	nr. top of Pakhuis Pass 12 km from Clanwilliam
AcCSIRO 035	3219CA	06.10.1992	14km from Citrusdal on route Ceres
AcCSIRO 036	3319CD	05.10.1992	On route High Noon about 5 km from Villiersdorp junction
AcCSIRO 037	3419AB	05.10.1992	9km from Genedendal on route Villiersdorp
AcCSIRO 038	3419AB	05.10.1992	Matjiesdriif Farm Between Caledon and Greyton
AcCSIRO 039	3218BB	24.09.1992	Louis Leipolds Grave, Pakhuis Pass, Cedarberg
AcCSIRO 114	3420BC	15.06.1993	Potberg Mountain
AcCSIRO 146	3322AC	28.11.1991	Cango Caves near Oudshoorn
AcCSIRO 150	3420BC	08.09.1993	Potberg Mountain, De Hoop Nature Reserve
AcCSIRO 155	3419DB	18.08.1993	Haze-Vlakte Farm (22km W of Bredasdorp on route Elim)
AcCSIRO 162	3318CD	14.07.1993	Rhodes Memorial, Cape Town
AcCSIRO 171	3421AC	28.07.1993	4km from Vermaaklikheid junction travelling from Stilbaai
AcCSIRO 178	3420BC	27.07.1993	Potberg Mountain, De Hoop Nature Reserve, Bredasdorp District
	3218BB	24.09.1992	Leipolds Grave, Pakhuis Pass
	3419AB	05.10.1992	just beyond Genadendal junction on route Greyton ex Caledon
	3419AB	05.10.1992	Middelplaas farm 99km ex Genadendal on route Villiersdorp)
	3319CD	05.10.1992	High Noon Road
	3319CB	05.10.1992	Vredehoek Farm (slopes of Waaihoek Mountains)
	3319AC	06.10.1992	Mitchells Pass near Ceres
	3219CA	06.10.1992	Die Boom farm, 10km before Sandfontein junction Ceres to Citrusdal route
	3219CA	06.10.1992	19km ex Citrusdal on route Ceres
	3219CA	06.10.1992	14km ex Citrusdal on route Ceres
	3218BB	07.10.1992	12km from Clanwilliam nar top of Pakhuis Pass
	3420BC	15.06.1993	Potberg
	3319AB	06.07.1993	Hillside (17km West of Caledon on route Cape Town)
	3319DD	18.07.1993	Pat Busch Nature Reserve near Robertson
	3420BC	26.10.1993	Potberg
	3319AB	28.09.1993	Gydo Pass
<b><i>Asparagus alopecurus</i></b>			
AcCSIRO 097	3118DD	08.10.1992	Wiedouw farm base of Gifberge
AcCSIRO 118, 121	3017BD	25.09.1991	Darters Grave, S of Kamieskroon
AcCSIRO 119	2917DA	19.09.1990	Spektakelberg Pass
AcCSIRO 153	2917DA	26.08.1993	Spektakel Pass
	3017DB	25.09.1991	10km ex Garies on route Hondeklipbaai
	3118DD	08.10.1992	Colinshoek Farm (pass at base of Gifberge)
	2917DA	26.08.1993	Spektakelpass
	3017BD	19.09.1990	Darters Grave
<b><i>Asparagus juniperoides</i></b>			
AcCSIRO 117	2816BD	24.09.1991	Bloeddrif rd.
	2816DD	24.09.1991	54km South of Alexander Bay
	2816BD	27.08.1993	Bloeddrif rd.
<b><i>Asparagus fasciculatus</i></b>			
AcCSIRO 122	3319CD	05.10.1992	Spes Bona Farm (29km N of Villiersdorp)
AcCSIRO 123	3219CA	7.199	14km from Citrusdal on route Ceres
AcCSIRO 124	3218BB	03.05.1990	Clanwilliam Dam
	2917DB	23.09.1991	Hester Malan Nature Reserve
	3017DB	25.09.1992	10 km ex Garies on route Hondeklipbaai

APPENDIX 2 (cont.): CSIRO survey records of *Asparagus* (previously *Myrsiphyllum*) species

ACCESSION No.	QUARTER DEGREE SQAURE	DATE	LOCALITY
<i>Asparagus fasciculatus</i> (cont.)			
	3218AD	26.09.1991	5km North of Bontheuwel
	3319CD		Spes Bona Farm (29km ex Villiersdorp on route Worcester)
	3319BA	06.10.1992	Karooport
	3219CA	06.10.1992	19 km from Citrusdal on route Ceres
	3219CA	06.10.1992	14km from Citrusdal
	3119AC	07.10.1992	Niewoudville Reserve
	3118CC	08.10.1992	1.8km beyond Doringbaai on route Groothoekbaai
	3218AB	08.10.1992	Leipoltville
	3218AB	08.10.1992	400m from T-junction to Lamberts Bay ex Doornbaai
	3218AD	08.10.1992	Elandsbay T- junction
	3218CB	09.10.1992	Noordkuil farm
	3218CB	09.10.1992	near Aurora at Diepkuil junction
	3218CB	09.10.1992	Brakfontein farm between Aurora and Velddrif
	3318AA	09.10.1992	Langebaan
	3018AA	19.09.1990	on route Karasberg
<i>Asparagus declinatus</i>			
AcCSIRO 125	3420AD	20.08.1990	De Hoop Nature Reserve
AcCSIRO 126	3319CA	08.08.1992	Meisha junction North of Wellington
AcCSIRO 128	3119CD	07.10.1992	1.8 km S of Botterkloof Farm (on route Niewoudville from Clanwilliam)
AcCSIRO 129	3420BC	21.08.1990	Potberg Mountain, De Hoop Nature Reserve, Bredasdorp district
AcCSIRO 130	3419AD	22.08.1990	Hermanus (on coast)
AcCSIRO 131	3218AD	11.07.1990	Elandsbay
AcCSIRO 133	3218BB	10.07.1990	Clanwilliam Dam
AcCSIRO 157	3419DB	18.08.1993	Haze-Vlakte Farm, 22 km W of Bredasdorp on route Elim
	3218AD	26.09.1991	5km North of Bontheuwel
	3420BC	29.10.1991	Potberg
	3418AB	21.11.1991	Redhill
	3418AB	21.11.1991	Westlake Golf Club
	3419AB	05.10.1992	just past Genadendal junction on route Greyton from Caledon
	3319CB	05.10.1992	Vredehoek Farm (slopes of Waaihoek Mountains)
	3319CA	05.10.1992	Tevrede Farm (Ceres junction from Worcester)
	3218AB	08.10.1992	Leipoltville
	3218CB	09.10.1992	Noordkuil Farm
	3218CB	09.10.1992	near Aurora at Diepkuil junction
	3218CB	09.10.1992	Brakfontein Farm between Aurora and Velddrif
	3318AA	09.10.1992	Langebaan
	3420BC	15.06.1993	Potberg
	3419BC	06.07.1993	Hillside Farm (17km West of Caledon)
	3319DD	18.07.1993	Pat Busch Nature Reserve near Robertson
	3218BB	10.07.1990	Clanwilliam Dam
	3218AB	11.07.1990	Leipoltville
	3318AC	11.07.1990	Yzerfontein
	3420AD	20.08.1990	De Hoop Nature Reserve camp site
	3420BC	24.10.1990	Potberg
	3420BC	21.08.1990	Potberg
	3419AD	22.08.1990	Hermanus, along coast
	3420AD	24.10.1990	De Hoop Nature Reserve camp site
	3420AD	27.05.1991	De Hoop Nature Reserve camp site
	3420BC	27.05.1991	Potberg
	3420BC	30.08.1991	Potberg
	3418AB		Silvermine
<i>Asparagus volubilis</i>			
AcCSIRO 135	3327CA	04.09.1990	Fish River Mouth
AcCSIRO 136	3420AD	27.05.1991	De Hoop Nature Reserve (at campsite), Bredasdorp District
AcCSIRO 137	3118DD	08.10.1992	Wiedouw Farm at base of Gifberge
AcCSIRO 138	3218CB	09.10.1992	Noordkuil farm
AcCSIRO 158	3419DB	18.08.1993	Haze-Vlakte Farm, 22 km W of Bredasdorp on route Elim
AcCSIRO 176	3421AC	28.07.1993	Vermaaklikheid
AcCSIRO 179	3421AD	28.07.1993	Blikhuis Farm (10km from Stilbaai on route Gouritzmond)
AcCSIRO 180	3421AD	28.07.1993	1km NE of Jongensfontein village
AcCSIRO 181	3421AD	28.07.1993	Stilbaai West

APPENDIX 2 (cont.): CSIRO survey records of *Asparagus* (previously *Myrsiphyllum*) species.

ACCESSION No.	QUARTER DEGREE SQUARE	DATE	LOCALITY
<b><i>Asparagus volubilis</i> (cont.)</b>			
AcCSIRO 182	3421AC	28.07.1993	4km from Vermaaklikheid junction (on route Vermaaklikheid from Stilbaai)
	3327CA	12.11.1991	Fish River Mouth
	3326BC	10.06.1992	Settlers Dam, Grahamstown
	3327CA	13.06.1992	Fish River Mouth
	3218CB	09.10.1992	Noordkuil Farm
	3420BC	15.06.1993	Potberg
	3420AD	20.08.1990	De Hoop Nature Reserve camp site
	3420BC	21.08.1990	Potberg
	3327CA	04.09.1990	Fish River Mouth
	3420AD	24.10.1990	De Hoop Nature Reserve camp site
	3420BC	24.10.1990	Potberg
	3420BC	30.08.1991	Potberg
	3420BC	27.05.1991	Potberg
	3420AD	27.05.1991	De Hoop Nature Reserve camp site
	3422BB	28.08.1991	Lake Pleasant
	3420AD	08.09.1993	De Hoop Nature Reserve camp site
<b><i>Asparagus multifiberosus</i></b>			
AcCSIRO 006	3218BB	10.08.1990	Clanwilliam Dam
AcCSIRO 003	3218DB	06.10.1992	Piekenierskloof Pass (resort), Citrusdal area
AcCSIRO 004, 007	3218BB	07.10.1992	nr. top of Pakhuis Pass
AcCSIRO 005	3118DB	08.10.1992	Wiedouw Farm (at base Gifberge)
AcCSIRO 008	3119CD	07.10.1992	beyond Botterkloof Pass on route Niewoudville (near of Botterkloof farm)
AcCSIRO 009	3219AA	07.10.1992	Pakhuis farm at base Pakhuis Pass (25 km from Clanwilliam)
AcCSIRO 154	2917DA	26.08.1993	Spektakel Pass
	2917DB	23.09.1991	Hester Malan Nature Reserve
	3218DB	06.10.1992	Piekenierskloof
	3218BB	07.10.1992	Clanwilliam Dam
	3218BB	07.10.1992	near top of Pakhuis Pass (12km from Clanwilliam)
	3219AA	07.10.1992	Pakhuis Farm (25km from Clanwilliam, just beyond Pass)
	3119AC	07.10.1992	Niewoudville Reserve
	3119CD	07.10.1992	on route Niewoudville from Clanwilliam, 1.8km before Botterkloof Farm
	3218AB	08.10.1992	Leipoltville
	3118DD	08.10.1992	Colinshoek Farm (in pass at base of Gifberge)
	2917DA	26.08.1993	Spektakel Pass
	2917DB	25.08.1993	Hester Malan Nature Reserve
	3218BB	10.07.1990	Clanwilliam Dam
	3218BD	11.07.1990	Paleisheuvel Rd near Clanwilliam junction, 2.8km ex "Die Berg" junction
	3218AB	11.07.1990	Leipoltville
	2816DB	18.09.1990	16.7km ex Kuboes on route Lekkersing
	3018AA	19.09.1990	on route Karasberg
	3218BB	20.09.1990	Clanwilliam Dam
AcCSIRO 001	3017DD	25.09.1991	nr. Langkloof River (13km N of Kotzesrus)
AcCSIRO 002	3319BA	12.09.1992	nr. junction to Sutherland on Karoopoort to Calvinia Rd.
AcCSIRO 151	3119BD	26.08.1993	Akkerendam Nature reserve near Calvinia
<b><i>Asparagus ovatus</i></b>			
AcCSIRO 067	3218BC	11.07.1990	Nuwerus farm
AcCSIRO 068	3322AC/AD	28.11.1991	on route Cango Caves
AcCSIRO 069, 070, 071	3218AB	08.10.1992	Kookfontein Farm (Doringbaai junction on route Lambertsbay)
AcCSIRO 072	3218BB	07.10.1992	Clanwilliam Dam
AcCSIRO 073	3218AD	08.10.1992	Elands Bay on coast beyond fish factory
AcCSIRO 074, 085	3319CA	08.08.1992	Meisha Junction N of Wellington
AcCSIRO 075	3218BC	26.09.1991	Nuwerus farm
AcCSIRO 076, 077, 078	3218AB	26.09.1991	5km E of Elandsbay on route Leipoltville
AcCSIRO 079, 080	3218BB	10.07.1990	Clanwilliam Dam
AcCSIRO 081	3218BC	24.05.1990	Nuwerus farm
AcCSIRO 082	3322CB	28.11.1991	Dysseldorp near Oudshoorn
AcCSIRO 083	3218BB	24.09.1992	On N7 just South of Paleisheuvel junction at little dam
AcCSIRO 084	3219AA	24.09.1992	Biedouw Valley
AcCSIRO 087	3017BB	25.09.1991	Kamiesberg Pass near Kamieskroon
AcCSIRO 088	3327AD	12.11.1991	Hamburg (Ciskei)
AcCSIRO 089	2832BA	26.03.1992	Bangazi lake (Cape Vidal) StLucia Nautre Reserve

APPENDIX 2 (cont.): CSIRO survey records of *Asparagus* (previously *Myrsiphyllum*) species.

ACCESSION No.	QUARTER DEGREE SQUARE	DATE	LOCALITY
<i>Asparagus ovatus</i> (cont.)			
AcCSIRO 090	3327CA	12.11.1991	Fish River Mouth
AcCSIRO 091	3327BB	04.09.1990	Marine Drive East London
AcCSIRO 092	3326DA	12.11.1991	River Crossing, Waters Meet Nature Reserve
AcCSIRO 109		08.03.1993	near Addo
AcCSIRO 110	3327CA	18.11.1992	Fish river Mouth
AcCSIRO 111	3320CC	16.06.1993	Cogmans Kloof at river crossing
AcCSIRO 112	3320CC	16.06.1993	Cogmans Kloof at river crossing
AcCSIRO 113, 116	3320CC	16.06.1993	Bonnievale junction betw. Swellendam and Ashton
AcCSIRO 147	3218BB	25.07.1991	Clanwilliam Dam
AcCSIRO 177	3421AC	28.07.1993	Vermaaklikheid
	2917DB	23.09.1991	Hester Maian
	3218BC	26.09.1991	Nuwerus
	3218BC	26.09.1991	Zandberg
	3218AD	26.09.1991	near Elandsbay junction
	3327CA	12.11.1991	Fish River Mouth
	3326DB	12.11.1991	Port Alfred
	3326DA	12.11.1991	Waters Meet Nature Reserve
	3322CB	28.11.1991	Dysseldorp
	3322AC/AB	28.11.1991	Kango Valley
	3321BC	29.11.1991	Opzoek
	3321CA	29.11.1991	Groot River Bridge
	2832BA	26.03.1992	Bangazi Lake
	3327CA	13.06.1992	Fish River Mouth
	3319CA	11.08.1992	Meisha junction near Wellington
	3218BB	24.09.1992	On N7 on route Clanwilliam just before Paleisheuvel junction
	3219AA	24.09.1992	Biedouw Valley
	3218BB	06.10.1992	Clanwilliam Dam
	3119CD	07.10.1992	5.5km before Botterkloof Farm on route Niewoudville from Clanwilliam
	3118DD	08.10.1992	Wiedouw (at base of Gifberge)
	3218AB	08.10.1992	400m from junction to Lamberts Bay ex Doornbaai
	3218AB	08.10.1992	7.8km East of Lambertsbay junction ex Doornbaai
	3218AB	08.10.1992	Elandsbay junction
	3218AD	08.10.1992	Elandsbay beyond fish factory along coast
	3218CB	09.10.1992	Noordkuil Farm
	3218CB	09.10.1992	near Aurora at Diepkuil Junction
	3218CB	09.10.1992	Brakfontein farm between Aurora and Velddrif
	3318AA	09.10.1992	Langebaan
	3318AC	09.10.1992	Yzerfontein
	3318DB	15.10.1992	Paardeberg, near Helpmekaar Farm
	3318AD	15.10.1992	on route Mamre from Malmesbury, 4km from Mamre junction
	3318CB	15.10.1992	near junction Silverstroomstrand Rd. with N7
	3318CD	15.10.1992	near Bloubergstrand ex Melkbosstrand
	3320CC	18.10.1992	Montagu, at start of trail up kloof
	3327BB	01.03.1990	East London, Marine Drive
	3218BC	24.05.1990	Nuwerus farm
	3218BB	10.07.1990	Clanwilliam Dam
	3218BC	11.07.1990	Nuwerus farm
	3218AD	11.07.1990	Elandsbay on coast
	3327BB	04.09.1990	East London, Marine Drive
	3322CA	08.09.1990	Olifants River crossing on route Oudshoorn ex Mosselbay
	2917DD	19.09.1990	91km ex Garies on route Springbok
	3218BB	20.09.1990	Clanwilliam Dam
	3129DA		Silaka, South of Port St. Johns
AcCSIRO 094	3218AD	08.10.1992	Elandsbay beyond Fish factory
AcCSIRO 095	3218CD	27.09.1991	Boesmanskraal Farm (before Aurora junction on route Velddrif)
AcCSIRO 096	3218CD	27.09.1991	Boesmanskraal Farm (before Aurora junction on route Velddrif)
<i>Asparagus undulatus</i>			
AcCSIRO 093	2816DD	24.09.1991	54km South of Alexander Bay on Port Nolloth Road
AcCSIRO 152	3119BD	26.08.1993	Akkerendam Nature Reserve, near Calvinia

**Appendix 3:** Details of insect voucher specimens, relevant to the text, collected during the CSIRO survey of *Asparagus asparagoides* and other Asparagaceae. Identification of specimens was conducted by the Biosystematics division of the Plant Protection Research Institute (Pretoria).

**Key:** AcUCT = Accession number University of Cape Town, AcP = Pretoria Accession number

Accession No.'s	Family name	Species name	determiner (date)	Locality	Collection date	Collector/s	biological notes
AcUCT 373	Penthaleidae	<i>Halolydeus destructor</i> (Tucker)	M.K.P. Meyer (1993)	RSA, Lake Brenton 3404S 2302E	23.07.1991	C.A. Kleinjan	mites feed in groups on the surface of the cladodes of bridal creeper ( <i>A. asparagoides</i> ).
AcUCT 372	Thripidae	<i>Hercinothrips bicinctus</i> (Bagnall)	M. Stiller (1993)	RSA, Lake Brenton 3404S 2302E	23.07.1991	C.A. Kleinjan	collected from bridal creeper ( <i>A. asparagoides</i> )
AcUCT 375 (AcP 9329)	Chrysomelidae Criocerinae	<i>Crioceris</i> sp. 1	B. Grobbelaar (1993)	RSA, Giants Castle Game Reserve 2916S 2931E	22.10.1992	C.A. Kleinjan P.B. Edwards	associated with bridal creeper ( <i>A. asparagoides</i> )
AcUCT 380 (AcP 9330, AcP 9331)	Chrysomelidae Criocerinae	<i>Crioceris</i> sp. 2	B. Grobbelaar (1993)	RSA, aseasonal rainfall region of the Western Cape	02/03.1991	C.A. Kleinjan	associated with bridal creeper ( <i>A. asparagoides</i> )
AcUCT 387 (AcP 9327)	Chrysomelidae Criocerinae	<i>Crioceris nigropunctata</i> Lacordaire	B. Grobbelaar (1993)	RSA, Couga 3345S 2539E	02.03.1991	C.A. Kleinjan	collected on <i>Asparagus</i> prob. <i>capensis</i>
AcUCT 388 (AcP 9328)	Chrysomelidae Criocerinae	<i>Crioceris nigropunctata</i> Lacordaire	B. Grobbelaar (1993)	RSA, Cape Town Wynberg 3400S 1828E	08.01.1990	S. Tugwell	collected on <i>A. densiflorus</i> in garden larvae eat flowers and buds
AcUCT 390 (AcP 9332)	Chrysomelidae Galerucinae	<i>Palpoxena praetoriae</i> (Gahan)	B. Grobbelaar (1993)	RSA, Magaliesberg Breedsnek Pass 2552S 2726E	14.11.1991	C. A Kleinjan P.B. Edwards	collected on bridal creeper ( <i>A. asparagoides</i> ) (has also been recorded on <i>Maytenus heterophylla</i> and on grape vines, B. Grobbelaar - correspondence)
AcUCT 389	Chrysomelidae Allicinae	<i>Hespera</i> sp.	B. Grobbelaar (1993)	RSA, 9km E of Ncwadi railway siding 2948S 3006E	21.10.1992	C.A. Kleinjan P.B. Edwards	collected on bridal creeper ( <i>A. asparagoides</i> )
AcUCT 378	Curculionidae	<i>Brachycerus parilis</i> Haaf	R. Oberprieler (1993)	RSA, Lake Brenton 3404S 2302E	29.08.1992	C.A. Kleinjan P.Müller	noted feeding on bridal creeper ( <i>A. asparagoides</i> ) also found sitting on <i>A. plumosus</i> and <i>A. prob. densiflorus</i> close to bridal creeper plants.
AcUCT 382	Curculionidae	<i>Brachycerus</i> sp. prob. undescribed	R. Oberprieler (1993)	RSA, Cape peninsula, Red Hill 3412S 1825E	16.07.1992	C.A. Kleinjan P.B. Edwards P.Müller	Collected on south-western Cape form of <i>A. asparagoides</i> (weevil larvae collected from tubers, may be same species, not reared to date)
AcUCT 386	Curculionidae	<i>Brachycerus fectus</i> Haaf	R. Oberprieler (1993)	RSA, 12km N of Cookhouse 3240S 2553E	16.11.1989	C.A. Kleinjan J.K. Scott	Collected on <i>Asparagus</i> sp. previously in <i>Protasparagus</i>
AcUCT 383	Curculionidae	<i>Brachycerus cornutus</i> (Linnaeus)	R. Oberprieler (1993)	RSA, near Kransvlei farm 3214S 1850E	24.05.1991	C.A. Kleinjan P.B. Edwards	Collected on <i>Asparagus</i> sp. previously in <i>Protasparagus</i>
AcUCT 384	Curculionidae	<i>Brachycerus</i> sp. prob. undescribed	R. Oberprieler (1993)	RSA, near Kransvlei farm 3214S 1850E	24.05.1991	C.A. Kleinjan P.B. Edwards	Collected on <i>Asparagus</i> sp. previously in <i>Protasparagus</i>
AcUCT 385	Curculionidae	<i>Brachycerus setepennis</i> Fahraeus	R. Oberprieler (1993)	RSA, Tendele 2843S 2856E	23.10.1992	C.A. Kleinjan P.Müller	Collected on <i>Asparagus</i> sp. previously in <i>Protasparagus</i>
AcUCT 394	Tephritidae	<i>Ceratitidis (Ceratitidis) capitata</i> (Wiedemann)	M.W. Mansell (1993)	RSA, Kaaimans River Mouth 3400S 2233E	06.12.1990	C.A. Kleinjan	reared from fruit (eat pulp only) of <i>A. prob. densiflorus</i> (common name Mediterranean fruit fly, polyphagous, M.Mansell - correspondence)
AcUCT 395	Cecidomyiidae		M.W. Mansell (1993)	RSA, Lake Brenton 3404S 2302E	29.05.1991	C.A. Kleinjan	emerged from "bushy cladode gall" of <i>A. plumosus</i>

Appendix 3 (Cont.) : Details of insect voucher specimens

Accession No.'s	Family name	Species name	determiner (date)	Locality	Collection date	Collector/s	biological notes
AcUCT 396	Cecidomyiidae		M.W. Mansell (1993)	RSA, Mtunzini 2857S 3145E	06.04.1989	C.A. Kleinjan J.K.Scott	from cladode gall of <i>A. falcatus</i> .
AcUCT 422	Cecidomyiidae	no further identification possible	M.W. Mansell (1993)	RSA, Lake Pleasant Hotel environs 3402S 2250E	08-12.03.1993	C.A. Kleinjan P.Müller	Emerged from cocoons collected from container with growth tip galls of Asparagaceae spp. ( <i>A. asparagoides</i> , <i>A. prob. densiflorus</i> , <i>A. plumosus</i> )
AcUCT 423	Cecidomyiidae		M.W. Mansell (1993)	RSA, Kaaimans River Mouth 3400S 2233E	08-12.03.1993	C.A. Kleinjan P.Müller	Emerged from cocoons collected from container with growth tip galls of Asparagaceae spp. ( <i>A. asparagoides</i> , <i>A. prob. densiflorus</i> , <i>A. plumosus</i> )
AcUCT 414	Noctuidae Acontinae	<i>Zalaca snelleni</i> (Wallengren)	M. Krüger (1993)	RSA, Kaaimans River Mouth 3400S 2233E	06.12.1989	C.A. Kleinjan	reared from fruit of bridal creeper ( <i>A. asparagoides</i> )
AcUCT 415	Noctuidae Acontinae	<i>Zalaca snelleni</i> (Wallengren)	M. Krüger (1993)	RSA, Paradise Camp 2452S 3053E	15.02.1991	C.A. Kleinjan	reared from fruit of bridal creeper ( <i>A. asparagoides</i> )
AcUCT 416	Noctuidae Acontinae	<i>Zalaca snelleni</i> (Wallengren)	M. Krüger (1993)	RSA, Kromdraai Farm 2354S 2956E	15.02.1991	C.A. Kleinjan	reared from fruit of bridal creeper ( <i>A. asparagoides</i> )
AcUCT 417	Noctuidae Acontinae	<i>Zalaca snelleni</i> (Wallengren)	M. Krüger (1993)	RSA, Port Edward 3103S 3013E	27.04.1990	C.A. Kleinjan P.B. Edwards	reared from fruit of <i>A. prob. densiflorus</i>
AcUCT 419	Noctuidae Acontinae	<i>Zalaca snelleni</i> (Wallengren)	M. Krüger (1993)	RSA, Kransvlei Farm near Clanwilliam 3214S 1850E	24.05.1990	C.A. Kleinjan	reared from fruit of <i>A. prob. laticinus</i>
AcUCT 420	Noctuidae Acontinae	<i>Zalaca snelleni</i> (Wallengren)	M. Krüger (1993)	RSA, Hermanus 3425S 1916E	04.04.1991	C.A. Kleinjan E.M. Brown	reared from fruit of <i>A. prob. aethiopicus</i>
AcUCT 418	Noctuidae Acontinae	<i>Coccidiphaga scitula</i> - group	M. Krüger (1993)	RSA, Port Edward 3103S 3013E	27.04.1990	C.A. Kleinjan P.B. Edwards	reared from fruit of <i>A. prob. densiflorus</i>
AcUCT 401	Noctuidae Acronictinae	<i>Euplexia augens</i> Felder and Rogenhofer	M. Krüger (1993)	RSA, Giants Castle Game Reserve 2916S 2931E	19.03.1992	C.A. Kleinjan P.B. Edwards	larva collected from and reared on bridal creeper ( <i>A. asparagoides</i> )
AcUCT 405	Noctuidae Acronictinae	<i>Euplexia augens</i> Felder and Rogenhofer	M. Krüger (1993)	RSA, Cape Town Wynberg 3400S 1829E	17.02.1992	C.A. Kleinjan	larva from cultivated <i>A. asparagoides</i> and <i>A. juniperoides</i> .
AcUCT 407	Noctuidae Acronictinae	<i>Euplexia augens</i> Felder and Rogenhofer	M. Krüger (1993)	RSA, Lake Brenton 3404S 2302E	29.08.1992	C.A. Kleinjan	larva collected from and reared on bridal creeper ( <i>A. asparagoides</i> )
AcUCT 404	Noctuidae Acronictinae	<i>Caradrina atriluna</i> (Guenée)	M. Krüger (1993)	RSA, Clanwilliam Dam 3214S 1855E	26.09.1991	C.A. Kleinjan	larva collected from and reared on <i>A. ovatus</i>
AcUCT 406	Noctuidae Cucullinae	<i>Cucullia terreus</i> Felder and Rogenhofer	V.M. Uys (1993)	RSA, Cape Town Wynberg 3400S 1829E	17.02.1992	C.A. Kleinjan	larva from cultivated <i>A. asparagoides</i> and <i>A. juniperoides</i> .
AcUCT 403	Noctuidae Noctuinae	<i>Lycophotia oliveata</i> (Hampson)	V.M. Uys (1993)	RSA, 9km E of Ncwadi railway siding 2948S 3006E	17.03.1992	C.A. Kleinjan	larvae collected and feeds on bridal creeper ( <i>A. asparagoides</i> )
AcUCT 410	Noctuidae Noctuinae	<i>Lycophotia oliveata</i> (Hampson)	V.M. Uys (1993)	RSA, Cape Town Kirstenbosch 3359S 1826E	06.1991	C.A. Kleinjan	larva collected from and reared on bridal creeper ( <i>A. asparagoides</i> )
AcUCT 430	Noctuidae Noctuinae	<i>Lycophotia oliveata</i> (Hampson)	V.M. Uys (1993)	RSA, Southwell 3332S 2641E	19.11.1992	C.A. Kleinjan P.B. Edwards	larva collected from and reared on bridal creeper ( <i>A. asparagoides</i> )

Appendix 3 (Cont.) : Details of insect voucher specimens

Accession No.'s	Family name	Species name	determiner (date)	Locality	Collection date	Collector/s	biological notes
AcUCT 399	Noctuidae Noctuinae	<i>Agrotis</i> sp.	V.M. Uys (1993)	RSA, Lake Pleasant Hotel environs 3402S 2250E	20.03.1991	C.A. Kleinjan	larva collected from and reared on bridal creeper ( <i>A. asparagoides</i> )
AcUCT 379	Eulophidae			RSA, Sedgefield 3402S 2248E	19.03.1991	C.A. Kleinjan	gregarious parasite of <i>Crioceris</i> sp. 2 associated with bridal creeper ( <i>A. asparagoides</i> )

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**APPENDIX 4 : The distribution of selected natural enemies of bridal creeper, the south-western Cape form of *A. asparagoides* and other *Asparagus* spp. previously in *Myrsiphyllum* .**

(Key: (bc) = bridal creeper or widespread form of *A. asparagoides*, (SWC) = southwestern Cape form of *A. asparagoides*)

PLANT SP.	LOCALITY	GRID REF.	<i>Puccinia myrsiphyllii</i>	<i>Eurytoma</i> sp.	<i>Zalaca snelleni</i>	<i>Zygina</i> sp.	<i>Crioceris</i> sp. 1	<i>Crioceris</i> sp. 2	Growth tip galls	<i>Brachycerus</i> sp.	<i>Brachycerus parilis</i>
<i>A. alopecurus</i>	Darter's Grave (S. of Kamieskroon)	3018 S 1754 E	x								
<i>A. alopecurus</i>	Spektakelpass	2940 S 1738 E	x								
<i>A. asparagoides</i> (bc)	Alexandra Forest	3342 S 2622 E		x		x					
<i>A. asparagoides</i> (bc)	Awoka Farm	3433 S 1930 E	x	x							
<i>A. asparagoides</i> (bc)	Barberton	2543 S 3101 E	x								
<i>A. asparagoides</i> (bc)	betw. Stormsvlei and Bonnievale	3403 S 2005 E		x							
<i>A. asparagoides</i> (bc)	Boknes	3344 S 2637 E						x			
<i>A. asparagoides</i> (bc)	Brenton - on - Sea	3404 S 2302 E				x					
<i>A. asparagoides</i> (bc)	Brenton Lake	3404 S 2302 E	x	x	x	x		x	x		x
<i>A. asparagoides</i> (bc)	Cannon Rocks	3345 S 2631 E		x		x		x	x		
<i>A. asparagoides</i> (bc)	Drakensberg Gardens	2945 S 2914 E				x	x				
<i>A. asparagoides</i> (bc)	Fish River Mouth	3330 S 2708 E		x	x	x			x		
<i>A. asparagoides</i> (bc)	Hazevlakte Farm	3438 S 1951E				x					
<i>A. asparagoides</i> (bc)	Giants Castle	2916 S 2931 E	x	x		x	x				
<i>A. asparagoides</i> (bc)	Hillside Farm (nr. Caledon)	3420 S 1938 E	x			x					
<i>A. asparagoides</i> (bc)	Joubertsdal Farm (nr. Swellendam)	3359 S 2016 E	x	x	x	x			x		
<i>A. asparagoides</i> (bc)	Kaaimans River Mouth	3400 S 2233 E		x	x	x		x	x		
<i>A. asparagoides</i> (bc)	Kaapse Hoop	2531 S 3047 E			x	x					
<i>A. asparagoides</i> (bc)	Kenton-on-Sea	3340 S 2640 E	x								
<i>A. asparagoides</i> (bc)	Knysna Heads	3405 S 2304 E		x							
<i>A. asparagoides</i> (bc)	Kromdraai Farm (nr Magoebaskloof)	2354 S 2956 E	x	x	x	x					
<i>A. asparagoides</i> (bc)	Kweekkraal (nr. Riversdale)	3406 S 2110 E	x			x			x		
<i>A. asparagoides</i> (bc)	Lake Pleasant	3402 S 2250 E	x	x	x	x		x	x		
<i>A. asparagoides</i> (bc)	Moneyworth Farm	3338 S 2640 E				x			x		
<i>A. asparagoides</i> (bc)	Nachtwacht Farm (8km South of Bredasdorp)	3435 S 2007 E	x	x	x	x		x		x(?)	

APPENDIX 4 (Cont.) : The distribution of selected natural enemies of bridal creeper, the south-western Cape form of *A. asparagoides* and other *Asparagus* spp. previously in *Myrsiphyllum*.

PLANT SP.	LOCALITY	GRID REF.	<i>Puccinia myrsiphylli</i>	<i>Eurytoma</i> sp.	<i>Zalaca sneifeni</i>	<i>Zygina</i> sp.	<i>Crioceris</i> sp. 1	<i>Crioceris</i> sp. 2	Growth tip galls	<i>Brachycerus</i> sp.	<i>Brachycerus parifis</i>
<i>A. asparagoides</i> (bc)	Natures Valley	3359 S 2334 E		x							
<i>A. asparagoides</i> (bc)	9km before Ncwadi Siding on Richmond Bulwer Rd.	2948 S 3006 E	x			x					
<i>A. asparagoides</i> (bc)	Ngome	2749 S 3121 E				x					
<i>A. asparagoides</i> (bc)	Jones Farm (5km E of Bathurst on route Kleinemonde)	3330 S 2652 E		x							
<i>A. asparagoides</i> (bc)	Old George/Knysna Rd	3358 S 2232 E		x		x		x			
<i>A. asparagoides</i> (bc)	near Kleinemonde	3333 S 2701 E		x							
<i>A. asparagoides</i> (bc)	Paradise Camp	2452 S 3053 E	x		x	x					
<i>A. asparagoides</i> (bc)	Pat Busch Nature reserve	3347 S 2000 E	x								
<i>A. asparagoides</i> (bc)	Phantom Pass	3401 S 2300 E	x	x	x	x		x	x		
<i>A. asparagoides</i> (bc)	Potberg	3422 S 2033 E	x	x	x	x		x			
<i>A. asparagoides</i> (bc)	Sedgefield	3402 S 2248 E	x	x	x	x		x	x		
<i>A. asparagoides</i> (bc)	Skoongesig Farm (6,5 km West of Caledon)	3415 S 2027 E	x								
<i>A. asparagoides</i> (bc)	Southwell	3332 S 2641 E		x	x	x					
<i>A. asparagoides</i> (bc)	St Francis Bay	3410 S 2450 E	x	x		x					
<i>A. asparagoides</i> (bc)	Stanley Bush Kop (nr. Pilgrims Rest)	2456 S 3048 E	x			x					
<i>A. asparagoides</i> (bc)	Stilbaai Wes	3422 S 2124 E				x					
<i>A. asparagoides</i> (bc)	Tendele	2843 S 2856 E		x	x	x			x		
<i>A. asparagoides</i> (bc)	Tsitsikama National Park	3330 S 2354 E		x							
<i>A. asparagoides</i> (SWC)	De Hoop Vlei	3429 S 2026 E									x
<i>A. asparagoides</i> (SWC)	Hangklip Rd.	3422 S 1850 E		x							
<i>A. asparagoides</i> (SWC)	Karbonkelberg	3403 S 1820 E		x		x					x
<i>A. asparagoides</i> (SWC)	Paarl Rock	3344 S 1856 E		x		x					
<i>A. asparagoides</i> (SWC)	Princess Vlei	3403 S 1829 E		x							
<i>A. asparagoides</i> (SWC)	Red Hill	3412 S 1825 E		x	x	x					x
<i>A. asparagoides</i> (SWC)	Sea Farm (Betty's Bay)	3422 S 1852 E				x					x
<i>A. asparagoides</i> (SWC)	Silvermine	3406 S 1826 E		x		x					x
commercial asparagus	Donald Cook, Tarlton	2604 S 2738 E		x	x						
<i>A. declinatus</i>	Potberg	3422 S 2033 E		x	x						
<i>A. fasciculatus</i>	14km ex Citrusdal on route Ceres	3237 S 1908 E		x							
<i>A. fasciculatus</i>	Spes Bona Farm (29 km N Of Villiersdorp)	3348 S 1926 E		x							

APPENDIX 4 (Cont.) : The distribution of selected natural enemies of bridal creeper, the south-western Cape form of *A. asparagoides* and other *Asparagus* spp. previously in *Myrsiphyllum*.

PLANT SP.	LOCALITY	GRID REF.	<i>Puccinia myrsiphyllii</i>	<i>Eurytoma</i> sp.	<i>Zalaca snelleni</i>	<i>Zygina</i> sp.	<i>Crioceris</i> sp. 1	<i>Crioceris</i> sp. 2	Growth tip galls	<i>Brachycerus</i> sp.	<i>Brachycerus parilis</i>
<i>A. fasciculatus</i>	4.7km before Paalkraal junction on route Niewoudtville			x							
<i>A. kraussianus</i>	Middelplaas farm (9km W of Genadendal on route Villiersdorp)	3404 S 1928 E		x		x					
<i>A. kraussianus</i>	betw. Caledon & Greyton, just past Genadendal junction	3411 S 1924 E		x		x					
<i>A. kraussianus</i>	Potberg	3422 S 2033 E		x							
<i>A. multituberosus</i>	Clanwilliam Dam	3214 S 1855 E				x					
<i>A. multituberosus</i>	Niewoudtville Reserve	3122 S 1908 E		x							
<i>A. ovatus</i>	13km ex Papkuilsfontein on route Velddrif			x							
<i>A. ovatus</i>	4km from Mamre junction			x							
<i>A. ovatus</i>	Biedouw Valley	3209 S 1911 E		x		x					
<i>A. ovatus</i>	Bonnievale junction (Between Swellendam and Ashton)	3354 S 2012 E	x								
<i>A. ovatus</i>	Clanwilliam dam	3214 S 1855 E		x		x					
<i>A. ovatus</i>	Dysseldorp	3334 S 2226 E		x							
<i>A. ovatus</i>	Elandsbay	3219 S 1820 E		x	x						
<i>A. ovatus</i>	Elandsbay Junction (5km E of Elandsbay on route Leipoltville)	3218 S 1824 E		x	x						
<i>A. ovatus</i>	Groot Rivier Bridge (betw. Ladysmith and Barrydale)	3336 S 2108 E		x		x					
<i>A. ovatus</i>	Langebaan	3306 S 1802 E		x							
<i>A. ovatus</i>	Nuwerus farm	3221 S 1845 E			x						
<i>A. ovatus</i>	Opsoek Farm	3329 S 2132 E		x		x					
<i>A. ovatus</i>	near Helpmekaar Farm (N base of Perdeberg)	3333 S 1848 E		x							
<i>A. ovatus</i>	Varsfontein Farm (8 km past Doornbaai junction betw. Lambertsbay and Clanwilliam)	3207 S 1826 E		x							
<i>A. ovatus</i>	Kookfontein Farm (junction Doringbaai to Lambertsbay)	3205 S 1822 E		x							
<i>A. ovatus</i>	on route Cango Caves			x							
<i>A. ovatus</i>	Port Alfred	3336 S 2654 E		x							
<i>A. ovatus</i>	Vermaaklikheid	3419 S 2102 E	x								
<i>A. volubilis</i>	De Hoop Nature reserve campsite	3427 S 2024 E	x								
<i>A. volubilis</i>	Haze-vlakte Farm (22km West of Bredasdorp)	3438 S 1951 E	x								
<i>A. volubilis</i>	Potberg	3422 S 2033 E	x								
<i>A. volubilis</i>	Vermaaklikheid	3419 S 2102 E	x								
<i>A. volubilis</i>	Nachtwacht Farm (8km South of Bredasdorp)	3435 S 2007 E	x								
<i>A. volubilis</i>	Fish River Mouth	3330 S 2708 E	x								

Appendix 5: Incidence of parasitism of *Eurytoma* sp. associated with *Asparagus asparagoides*.

The numbers of male and female *Eurytoma* sp. per sample are also listed.

(The samples below were all collected from the widespread form of *A. asparagoides*, grid references for the localities are listed in Chapter 2)

Date	Locality	Sample #	<i>Eurytoma</i> (f)	<i>Eurytoma</i> (m)	<i>Eurytoma</i> (total)	Parasite 1 (f)	Parasite 1 (m)	Parasite 2 (f)	Parasite 2 (m)	Parasite 3 (f)	Parasite 3 (m)	Parasite 4 (f)	Parasite 4 (m)	Parasite (total)	Parasite (%)
Nov-91	Brenton Lake	1	4	0	4									0	0.0
Nov-91	Brenton Lake	2	5	1	6									0	0.0
Nov-91	Brenton Lake	3	35	20	55									0	0.0
Nov-92	Brenton Lake	1	11	8	19									0	0.0
Nov-92	Brenton Lake	2	47	28	75									0	0.0
Nov-92	Brenton Lake	3	3	3	6									0	0.0
Nov-92	Brenton Lake	4	5	6	11									0	0.0
Nov-92	Brenton Lake	5	7	8	15									0	0.0
Nov-92	Brenton Lake	6	8	17	25									0	0.0
Nov-92	Cannon Rocks	1	2	2	4									0	0.0
Nov-92	Cannon Rocks	2	17	15	32									0	0.0
Nov-92	Cannon Rocks	4	11	4	15									0	0.0
Nov-92	Cannon Rocks	5	26	15	41									0	0.0
Oct-92	Giants Castle	1	20	16	36									0	0.0
Oct-92	Giants Castle	2	46	59	105					1				1	0.9
Oct-92	Giants Castle	3	1	3	4	3	1							4	50.0
Oct-92	Giants Castle	4	8	6	14	9	3							12	46.2
Oct-92	Giants Castle	5	5	3	8									0	0.0
Oct-92	Giants Castle	6	38	32	70									0	0.0
Nov-91	Kaaimans River Mouth	4	2	0	2									0	0.0
Nov-92	Kaaimans River Mouth	1	46	33	79									0	0.0
Nov-92	Kaaimans River Mouth	2	30	23	53									0	0.0
Nov-92	Kaaimans River Mouth	3	38	33	71									0	0.0
Nov-92	Kaaimans River Mouth	4	21	18	39									0	0.0
Nov-92	Kaaimans River Mouth	5	11	6	17									0	0.0
Nov-92	Lake Pleasant	1	33	34	67									0	0.0
Nov-92	Lake Pleasant	2	43	31	74									0	0.0
Nov-92	Lake Pleasant	3	40	16	56									0	0.0
Nov-92	Lake Pleasant	4	38	21	59									0	0.0
Nov-92	Lake Pleasant	5	24	6	30									0	0.0
Nov-92	Lake Pleasant	6	30	27	57									0	0.0
Sep-93	Nachtwacht	1	54	95	149									0	0.0
Sep-93	Nachtwacht	2	103	117	220									0	0.0
Sep-93	Nachtwacht	3	9	14	23									1	4.2
Sep-93	Nachtwacht	4	13	22	35									0	0.0
Sep-93	Nachtwacht	5	56	72	128									0	0.0
Oct-92	Nachtwacht	1	21	31	52									0	0.0
Oct-92	Nachtwacht	2	14	13	27									0	0.0
Oct-92	Nachtwacht	3	36	24	60									0	0.0
Oct-92	Nachtwacht	4	11	11	22								2	2	8.3
Oct-92	Nachtwacht	5	39	27	66									0	0.0
Nov-91	Phantom Pass	1	58	52	110									0	0.0
Nov-91	Phantom Pass	2	31	16	47									0	0.0
Nov-91	Phantom Pass	3	13	6	19									0	0.0
Nov-91	Phantom Pass	4	19	21	40									0	0.0
Nov-91	Phantom Pass	5	48	29	77									0	0.0
Nov-91	Phantom Pass	6	1	0	1									0	0.0
Nov-92	Phantom Pass	1	25	27	52									0	0.0
Nov-92	Phantom Pass	2	26	25	51									0	0.0
Nov-92	Phantom Pass	3	27	15	42									0	0.0
Nov-92	Phantom Pass	4	35	27	62									0	0.0
Nov-92	Phantom Pass	5	13	8	21									0	0.0
Nov-92	Phantom Pass	6	45	34	79									0	0.0
Nov-92	Phantom Pass	7	32	25	57									0	0.0
Nov-92	Phantom Pass	9	12	14	26									0	0.0
Sep-93	Potberg	1	12	31	43									0	0.0
Sep-93	Potberg	2	10	8	18									0	0.0
Nov-92	Sedgefield	1	8	3	11									0	0.0
Nov-92	Sedgefield	3	20	11	31									0	0.0
Nov-92	Sedgefield	5	40	14	54									0	0.0
Nov-92	Southwell	1	11	34	45									0	0.0
Sep-93	Swellendam	1	38	40	78									0	0.0
Sep-93	Swellendam	2	57	61	118									0	0.0
Sep-93	Swellendam	3	45	69	114									0	0.0
Sep-93	Swellendam	4	15	21	36									0	0.0
Sep-93	Swellendam	5	27	38	65			1	1					2	3.0
Oct-92	Tendele	1	26	9	35									0	0.0
Oct-92	Tendele	2	20	9	29									0	0.0
TOTAL		68	1725	1567	3292									22	0.7