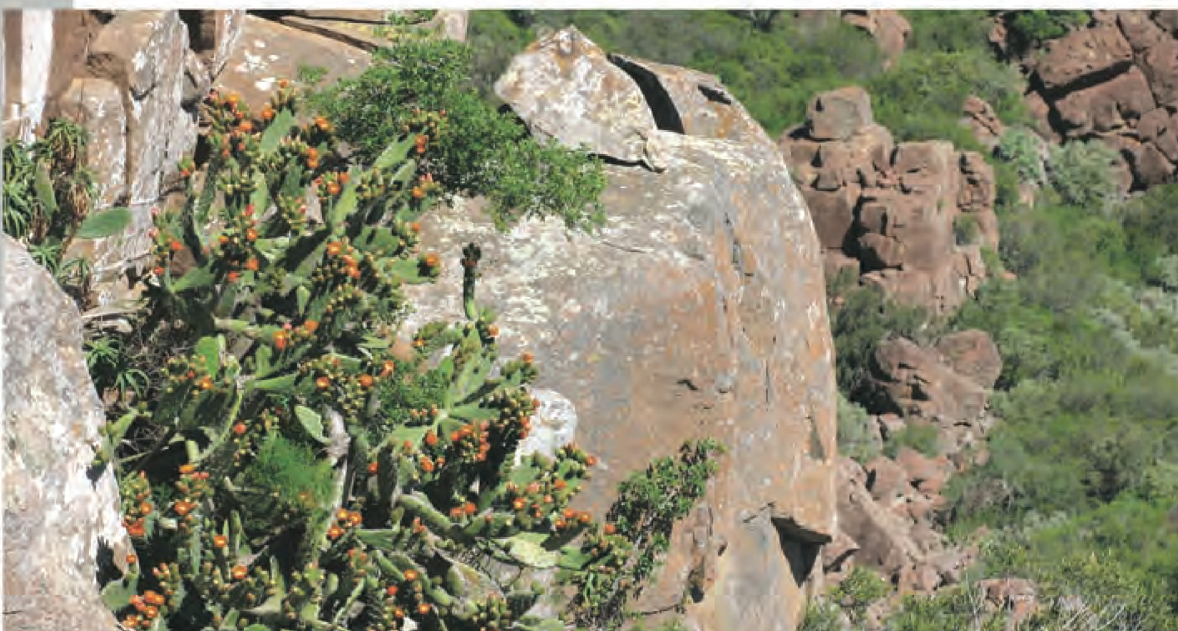
Abc Taxa

Naturalised and invasive succulents of southern Africa

M. Walters, E. Figueiredo, N.R. Crouch,
P.J.D. Winter, G.F. Smith,
H.G. Zimmermann and B.K. Mashope



Volume 11 (2011)

Abc Taxa the Series of Manuals Dedicated to Capacity Building in Taxonomy and Collection Management

WITH THE SUPPORT OF THE BELGIAN DEVELOPMENT COOPERATION .be

Editors

Yves Samyn - Zoology (non African)

Belgian Focal Point to the Global Taxonomy Initiative
Royal Belgian Institute of Natural Sciences
Rue Vautier 29, B-1000 Brussels, Belgium
yves.samyn@naturalsciences.be

Didier VandenSpiegel - Zoology (African)

Department of African Zoology
Royal Museum for Central Africa
Chaussée de Louvain 13, B-3080 Tervuren, Belgium
dvdspiegel@africamuseum.be

Jérôme Degreef - Botany

Belgian Focal Point for the Global Strategy for Plant Conservation
National Botanic Garden of Belgium
Domaine de Bouchout, B-1860 Meise, Belgium
jerome.degreef@br.fgov.be

Instructions to authors

http://www.abctaxa.be

ISSN 1784-1283 (hard copy)
ISSN 1784-1291 (on-line pdf)
D/2011/0339/2

Naturalised and invasive succulents of southern Africa

by

Michele Walters

Natural Resources and Environment, Council for Scientific and Industrial Research, P.O. Box 395, 0001 Pretoria, South Africa and Centre for Wildlife Management, Department of Animal and Wildlife Science, University of Pretoria, 0002 Pretoria, South Africa
Email: mwalters@csir.co.za

Estrela Figueiredo

Department of Botany, P.O. Box 77000, Nelson Mandela Metropolitan University, Port Elizabeth, 6031 South Africa and Centre for Functional Ecology, Departamento de Ciências da Vida, Universidade de Coimbra, 3001-455 Coimbra, Portugal
Email: estrelafigueiredo@hotmail.com

Neil R. Crouch

Ethnobotany Unit, South African National Biodiversity Institute, P.O. Box 52099, 4007 Berea Road, South Africa and School of Chemistry, University of KwaZulu-Natal, 4041 Durban, South Africa
Email: n.crouch@sanbi.org.za

Pieter J.D. Winter

Biodiversity Information Management Unit, South African National Biodiversity Institute, P/Bag X7, 7735 Claremont, South Africa.
Email: p.winter@sanbi.org.za

Gideon F. Smith

Biosystematics and Biodiversity Collections, South African National Biodiversity Institute, Private Bag X101, 0001 Pretoria, South Africa; H.G.W.J. Schweickerdt Herbarium, Department of Plant Science, University of Pretoria, 0002 Pretoria, South Africa and Centre for Functional Ecology, Departamento de Ciências da Vida, Universidade de Coimbra, 3001-455 Coimbra, Portugal
Email: g.smith@sanbi.org.za

Helmuth G. Zimmermann

Helmuth G. Zimmermann & Associates (Central), P.O. Box 974, 0043 Pretoria, South Africa
Email: zimmermannhelmuth@gmail.com

Barbara K. Mashope

Early Detection and Rapid Response Program, South African National Biodiversity Institute, P/Bag X7, 7735 Claremont, South Africa.
Email: b.mashope@sanbi.org.za

Captions to figures for *Naturalised and invasive succulents of southern Africa*

Front cover. *Opuntia ficus-indica* (L.) Mill. thriving on an inaccessible cliff ledge in the Karoo, Graaff-Reinet, South Africa. (Picture by Neil R. Crouch)

Half-title page. The exotic *Agave americana* L. var. *americana*, *Echinopsis schickendantzii* F.A.C.Weber and *Cylindropuntia pallida* (Rose) F.M.Knuth firmly established in South Africa's Karoo. (Picture by Helmuth G. Zimmermann)

Contributors:

James S. Boatwright
Thulisile P. Jaca
Takalani D. Malotsha
Rethabile F. Motloung

Foreword

Many books on plant invasions are published every year dealing with various aspects of the field, ranging from regional atlases to conference proceedings covering a variety of topics and compendia on theoretical issues related to invasion biology with chapters written by invited authors. The first question that a potential buyer or reader of this book would consider is whether they require yet another book on plant invasions, even if it is from South Africa, a country that is greatly impacted by invasive plants. In the current literature the majority of books on invasions focus on the ecology of the organisms. However, while this volume on invasive succulents does provide some ecological and historical background, it is primarily a taxonomic treatment, making it special among the plethora of books bearing the word "invasive" in their title.

Succulents are an important group in terms of their position amongst invasive plants. Although Weber's compendium of invasive plants of the world from 2003 lists only nine species of perennial succulents among more than 400 global invaders, the group includes some of the prominent invasive species. Everyone interested in biological invasions is aware of the control of *Opuntia* Mill. in Australia using the moth *Cactoblastis cactorum*, which was one of the first examples of successful biological control on invasive plants. In heavily impacted parts of the world, succulent invaders have transformed habitats, exerting a range of ecological and economic impacts. This is true both in South Africa and other parts of the world. Although most of the world's most noxious succulent invaders come from North America, South Africa itself has donated some prominent succulent invaders, such as *Carpobrotus edulis* (Fig. 1), *Mesembryanthemum crystallinum* or *Conicosia pugioniformis* to other parts of the world.

As a rule in biological invasions, only a few taxa from the whole species pool are successful as invaders. However, it is also important to be aware of those that are not successful, as future invaders could be recruited from taxa that are currently naturalised. Therefore, comprehensive regional accounts on alien species should be praised. This volume deals with about seventy succulent species that have become naturalised in South Africa and neighbouring countries, providing detailed descriptions and illustrations. However, it is not just an atlas of alien succulents because this information is placed into a wider ecological and historical context through chapters on their ecological impacts, the history of their invasion in South Africa, pathways of introduction and reasons for their invasiveness, and also legislation on invasive species in South Africa. An outline of the current classification of each of the families and genera is provided, along with dichotomous identification keys, and a guide on how to collect succulents for deposition in an herbarium.

Fig. 1. *Carpobrotus edulis* (L.) N.E.Br. subsp. *edulis* (sour fig) is an indigenous South African succulent that has become established in other parts of the world. (Picture by Neil R. Crouch)

The taxonomic emphasis present throughout the book highlights the role of taxonomy in current research on biological invasions. Field botanists and researchers in invasion biology are often confronted with new species that may have come to their regions from virtually any part of the world. The ability to identify new invaders is essential to develop an early warning system and facilitate immediate response to potential invasions that may cause problems in the future. Therefore, close cooperation between ecologists and taxonomists is vital for successful management of invasive species. This book exemplifies how fruitful such cooperation can be.

The authors state that the book is targeted at the general public, policymakers, fellow scientists, agricultural researchers, horticulturalists, customs officials, and commercial and subsistence farmers. Special consideration has been given to make it accessible to the general public. Indeed, one can imagine an enthusiastic amateur naturalist using the dichotomous keys contained in this book, as a guide on his or her field trips to identify the species he or she finds. Of equal importance is the fact that the user will *not* be able to identify some species, simply because they are not in the book and could therefore be future invaders. Fortunately the authors provide some guidance in such cases by providing information on how to collect an herbarium specimen and to seek expert help. Every collector knows how difficult it is to collect a succulent for an herbarium specimen resulting in succulents being fairly under-represented in herbaria. If the book contributes to improving this situation, it will gain even greater credibility.

Prof. Petr Pyšek, PhD
Institute of Botany of the Academy of Sciences of the Czech Republic
Průhonice, Czech Republic
22 December 2010

Abstract

Taxonomic information is provided for 69 exotic succulent plant species that have become naturalised or invasive - or may potentially do so - in South Africa and some of its neighbouring countries. Informative descriptive text and illustrations are provided for all the species, as well as synonymies and geographical distribution maps. Ancillary chapters cover brief introductions to the ecological impacts of invasiveness, a history of invasive succulents in South Africa, the means of introduction and reasons for their success, legislation governing invasive species in South Africa, and how to collect succulents for deposition in an herbarium. However, emphasis throughout is on the taxonomy of these species.

Keywords - alien species, early detection, eradication, invaders, naturalised, southern Africa, succulent plants

Table of contents

1. About this book

The primary aim of this book is to provide taxonomic information on the alien succulent plant species that have become established as part of the naturalised flora of southern Africa. The formal taxonomy of the species which form the main part of the book therefore includes descriptions of families, genera and species, synonymies, illustrations, and distribution information and maps. As far as possible the taxonomy is complemented with natural history observations and cultural information applicable to the species within both its natural and adopted distribution ranges. Given the devastating impact aliens can have on the natural environment, and by implication on human livelihoods, one of the primary objectives of the book is to bring the scourge of alien plant invaders to the attention of many. This book targets the general public, policymakers, fellow scientists, agricultural researchers, horticulturalists, customs officials, and commercial and subsistence farmers. For this reason much of the text is written in non-technical language that is easy to read and understand. We have deliberately opted for a broad definition of what constitutes alien and invasive plants, and species that have contributed extensively to habitat transformation, e.g. *Opuntia stricta* (Haw.) Haw. (sour prickly pear, suurturksvy) (Fig. 2), listed as amongst the 36 worst invasive alien plant species globally (Lowe *et al.*, 2000), as well as those that are little more than troublesome garden or crop weeds, e.g. *Portulaca oleracea* L. (purslane) (Fig. 3), are included in the book.

Fig. 2. *Opuntia stricta* (Haw.) Haw. (sour prickly pear) has contributed to serious habitat transformation in several countries. (Picture by Neil R. Crouch)

Fig. 3. *Portulaca oleracea* L. (purslane) is a widely distributed weed of cultivated lands. (Picture by Neil R. Crouch)

As far as possible we have followed the latest classification and nomenclature applicable to the invasive alien succulents of southern Africa. However, in a few instances we have opted not to use the latest classificatory suggestions; for example we prefer to retain the species of *Agave* L. (century plants) in the family Agavaceae rather than including them in the very broadly conceived Asparagaceae of the most recent Angiosperm Phylogeny Group proposal. In some instances the taxonomies of alien succulents that are firmly entrenched in South Africa—and have been so for decades—remain poorly understood locally and sometimes even in their native ranges, particularly in the case of the Cactaceae (cactus family). This publication therefore reflects the current state of our knowledge of the taxonomy of these, as well as the rest of the exotic succulent plants that have become established in natural settings in South Africa and sometimes in neighbouring countries, and beyond. The descriptions of the families and genera provided in this book cover the full variation of the taxa and therefore include the characters of the taxa naturalised in southern Africa.

The geographic coverage of the book is mainly South Africa, but several of the included species have become more widely established, occurring in neighbouring countries, and often much further afield. Where the information was available to us, we have also reflected the occurrence of the species beyond the borders of South Africa.

Chapters in the first part of the book cover several topics that are relevant to studies of biological invasions. These include the ecological impacts of invasiveness, a history of invasive succulents in South Africa, e.g. the means of introduction and reasons for their success, legislation governing invasive species in South Africa, and how to collect succulents for deposition in an herbarium.

In the second part of the book all the species are provided with informative taxonomic descriptions that are useful in identifying them, with special emphasis on those characters important in distinguishing them from related or similar-looking entities, in particular those known to be indigenous to South Africa. An outline of the current classification within each of the families and genera is provided, along with dichotomous identification keys. Colour and black and white images, line drawings, where available, and geographical distribution maps reflecting the best available knowledge, are provided for each taxon.

Past and present species occurrence data (from individual casual aliens to naturalised or invasive stands) for South Africa were obtained from as many sources as possible, including personal observations, interrogating the Agricultural Research Council's Southern African Plant Invaders Atlas (SAPIA), *SAPIA Newsletters* and the South African National Herbarium Pretoria (PRE) Computerised Information System (PRECIS). For other southern African countries, books on invaders, national plant checklists and websites, for instance, Swaziland's Alien Plants Database (http://www.sntc.org.sz/alienplants/index.asp), were used. Standard reference works such as published volumes of the *Flora of Southern Africa (FSA)* and *'Contributions to the FSA'*, an occasional column included in *Bothalia*, were also used and are referenced in the various chapters where the families are treated taxonomically. In the absence of systematic surveys of many of these species, however, occurrence data usually remain scanty.

The following abbreviations are used throughout the book for the five countries included in the *Flora of Southern Africa* region: B-Botswana; L-Lesotho; N-Namibia; S-Swaziland; SA-South Africa.

It should be noted that some common names given in the book are better known in other parts of the world and not widely used in southern Africa. They are listed here for the sake of completeness.

2. Biology and impact of invasive succulent plants

by James S. Boatwright, Gideon F. Smith, Helmuth G. Zimmermann, Thulisile P. Jaca, Rethabile F. Motloung and Takalani D. Malotsha

2.1. Invasive succulent plants in South Africa

Alien or exotic (non-native) plants can be defined as those that occur in a given area outside of their known, natural distribution due to intentional or accidental introduction through human activity. These plants are only considered to be invasive once they have become naturalised (i.e. reproduce successfully without human intervention) and are able to produce reproductively viable offspring significant distances away from the parent population (see Text Box 1 for useful definitions; Richardson *et al.*, 2000). The effects of invasive plants are often destructive to the natural environment and threaten the biodiversity of areas on which they encroach (Richardson & Van Wilgen, 2004).

South Africa has an extremely rich biodiversity, the richest temperate flora in the world, with 20 456 species occurring in the region (Germishuizen *et al*., 2006; Raimondo *et al.*, 2009). Of these 2 577 taxa are threatened with regional or global extinction. These threats are mainly through agriculture, urbanization, habitat loss and encroachment of alien invasive species (Raimondo *et al*., 2009). Currently, in South Africa more than 550 plant species are known to be contributing to the widespread transformation of once pristine habitats. Approximately 550 naturalised alien species are listed by the Southern African Plant Invaders Atlas (SAPIA) (Henderson, 2007). Of these, approximately 70 are succulents with fat (green or non-green) stems (Fig. 4), leaves (Fig. 5) or caudices (Fig. 6), of which almost half are members of the family Cactaceae. These plants are generally spiny, almost invariably leafless succulents characterised by the presence of areoles. All cactus growth occurs from areoles (reduced axillary shoots) (Fig. 7), which are usually evident as small white, yellow or brown furry ‘spots’ on the cactus plant bodies (Barthlott & Hunt, 1993; Smith, 2006a). A high number of succulent invaders - almost 20% of the recorded invasive plants - is unsurprising, as most succulents, cacti in particular, require very little aftercare and maintenance once in cultivation, and much of the South African landscape is comprised of arid to semi-arid regions in which succulents thrive, such as the Succulent Karoo, Nama-Karoo and Desert Biomes (Mucina & Rutherford, 2006).

Fig. 4. *Myrtillocactus geometrizans* (Pfeiff.) Console is an example of a stem succulent. (Picture by Gideon F. Smith)

Fig. 5. *Bryophyllum daigremontianum* Haw. is an example of a leaf succulent. (Picture by Neil R. Crouch)

Fig. 6. *Phytolacca dioica* L. of which the stem, especially towards the base, is quite succulent, making it popular among succulent collectors with large gardens. (Picture by Geoff R. Nichols)

Fig. 7. *Cylindropuntia imbricata* (Haw.) F.M.Knuth has stems that are sparsely dotted with spiny areoles. (Picture by Neil R. Crouch)

Text Box 1. Definitions relating to plant invasion ecology (from Richardson *et al.*, 2000).

Alien plant: Plant taxa that occur in a given area due to intentional or accidental introduction through humans (syn. exotic plants, non-native plants).

Casual alien plants: Alien plants which thrive and even reproduce in an area, but need repeated introductions for their persistence and do not form self-replacing populations.

Naturalised plants: Alien plants which successfully reproduce in an area and sustain populations over numerous life cycles without direct human intervention.

Invasive plants: Naturalised alien plants or native plants which reproduce, often at high frequency, a significant distance from the parent population and can potentially spread over large areas (native plants that become invasive are often referred to as "densifiers").

Weeds: Plants that are not necessarily alien and grow in areas where they are not wanted, usually with detectable economic or environmental effects (syn. pest plants, problem plants). Mostly associated with "crop weeds".

Transformers: Those invasive plants that change the character, condition, nature or form of ecosystems over a considerable area relative to the extent of that ecosystem.

Of course not all succulents found in South Africa are exotic. South Africa and its four immediate neighbours (Namibia, Botswana, Swaziland and Lesotho) harbour the richest succulent flora globally with over 4 700 such species having been recorded for the subcontinent (Smith *et al*., 1997).

In the South African context, many of the succulent plants now established as invasives were originally introduced into the country for economic purposes. One such well-known example is the prickly pear, *Opuntia ficus-indica* (L.) Mill. (Fig. 8). This member of the Cactaceae, probably introduced into South Africa during early European settlement of the Cape in the seventeenth century, is a multi-use commercial crop for arid regions where the fruit are eaten and the cladodes (fleshy, leaf-like stems), which are regarded as delicacies in their native Mexico and elsewhere (Zimmermann & Zimmermann, 1987; Brutsch & Zimmermann, 1993), are used as livestock fodder and vegetables (Van Wyk & Gericke, 2000). It has now become a serious invader in not only South Africa, but also Saudi Arabia, Yemen, Eritrea, Ethiopia, Madagascar, Hawaii and other countries. The near-cosmopolitan common garden weed *Portulaca oleracea* L. or purslane, the natural origin of which remains unresolved, was established at the southern tip of Africa to provide a source of Vitamin C for seafarers rounding the Cape (Smith & Figueiredo, 2010). Both these species have spread rapidly across the subcontinent and beyond, with the former having contributed extensively to the transformation of large tracts of arid landscapes in the southern African interior. Some South African plants are similarly introduced into other parts of the world for their usefulness or economic gain. The South African succulent, *Carpobrotus edulis* (L.) N.E.Br. is now invasive in coastal dunes of Australia, New Zealand, USA, and southern and western Europe (Roiloa *et al*., 2010). It was, and still is, widely used to stabilise dunes and road cuttings. Interestingly, there is one documented case where an indigenous succulent plant, *Aloe spectabilis* Reynolds, has become successfully established as a viable colony elsewhere in the country following its translocation to a suitable habitat over 100 years ago (Klopper *et al*., 2010). However, this is rare among the succulents of South Africa.

Fig. 8. *Opuntia ficus-indica* (L.) Mill. was introduced into South Africa as a fodder plant and for its sweet, edible fruit, here shown together with fruit of *Opuntia monocantha* Haw. on the right. (Picture by Helmuth G. Zimmermann)

2.2. Biology and success of succulent invasives

Exotic succulents can easily become established in regions remote from their areas of origin as their general biology and lack of specific natural enemies greatly assist their survival and spread in adopted countries. Firstly, succulents are well adapted to easily survive periods of drought, while some can additionally thrive under such and other adverse environmental and climatic conditions, including very low temperatures. One adaptation to drought tolerance is the reduction of water loss through stomatal closure during the day. Most vascular plants concentrate carbon dioxide (CO_2) for photosynthesis through C_3 carbon fixation which limits them to growing in moderate temperatures as RuBisCO, an enzyme which facilitates carbon fixation, binds more oxygen than CO_2 at higher temperatures (photorespiration) thus limiting photosynthesis (Keeley & Rundel, 2003). However, many succulent plants concentrate CO_2 through Crassulacean Acid Metabolism (CAM). The advantage of CAM is that it gives plants the ability to survive in dry environments because the stomata only open at night to fix CO_2, and stomatal closure during the day significantly reduces water loss (Keeley & Rundel, 2003; Lüttge, 2004). The fixed CO_2 becomes available during the day and increases the efficiency of photosynthesis. Adaptations to CAM generally include thickening of the leaves along with an increase in cell and vacuole size, reduced intercellular air spaces (IAS) and reduced length of mesophyll surface exposed to IAS per unit (Nelson *et al*., 2005). Most succulents are able to reproduce both from seed and through rooting of severed vegetative parts (clonal reproduction). Species with edible fruit are spread by frugivores, which increases the spatial distribution and density of these plants, the dispersal of species of *Opuntia* Mill. by crows and pale- and red-winged starlings in the Karoo region of South Africa being an example (Dean & Milton, 2000). Others such as *Opuntia aurantiaca* Lindl. (jointed cactus) (Fig. 9) and *Cylindropuntia fulgida* (Engelm.) F.M.Knuth var. *mamillata* (A.Schott ex Engelm.) Backeb. (boxing glove cactus), an emerging alien invasive in South Africa, spread exclusively by vegetative means in their adopted country. These plants are small shrubs that produce stem segments that are easily dislodged and quickly root when they fall from the mother plant (Fig. 10). These thorny segments may be distributed by animals such as livestock through attaching to their fur, or by moving water (J.S. Boatwright, *pers. obs.*). Lastly, many invasive succulents are thorny to varying degrees possibly to escape herbivory in order to protect the water stored in their stems. These extremely thorny invasive cacti, for example the jointed cactus and all the chollas (species of *Cylindropuntia* (Engelm.) F.M.Knuth), can cause considerable harm to small livestock and wildlife, and make handling of specimens of these plants by botanists and others cumbersome. Hares and even small antelope get immobilised, preventing movement and feeding which eventually leads to death. Many birds and small reptiles get impaled on the thorns (Fig. 11; H.G. Zimmermann, *pers. obs.*). This is in stark contrast to the co-adapted local fauna living in the Sonoran Desert (North America) where the chollas are native. Many animal species use these thorny thickets for their own protection, coping well with the barbed spines (Fig. 12).

Fig. 9. *Opuntia aurantiaca* Lindl. cladodes (stem segments) easily snap off when passing animals brush against plants. This is the primary way in which it is vegetatively spread. (Picture by Helmuth G. Zimmermann)

Fig. 10. New populations of *Cylindropuntia fulgida* (Engelm.) F.M.Knuth become established from severed stem segments. (Picture by Barbara K. Mashope)

Fig. 11. A bird that became impaled in the spines of *Cylindropuntia fulgida* (Engelm.) F.M.Knuth. (Picture by Helmuth G. Zimmermann)

Fig. 12. An animal nesting/hiding in the protection of the spines of an *Opuntia* species. (Picture by Helmuth G. Zimmermann)

All invasive succulent species were introduced without any of their natural enemies that prevent them from becoming invasive in their countries of origin. None of the local native phytophagous insect fauna has switched hosts to any of the 28 invasive cactus species, despite their abundance and more than a century of exposure. Due to the uniqueness of the Cactaceae their associated insect fauna is equally uniquely adapted to feed on these plants and are thus often extremely host specific. This explains in part why the success rate of biological control projects on cactus invaders is often higher than those of other plant families.

2.3. Impacts and control of invasion

Le Maitre *et al.* (2000) estimated that approximately 10.1 millions hectares of South Africa and Lesotho have been invaded by alien plants in general. Of the eight biomes found in South Africa (see Rutherford *et al*., 2006), the Western Cape Province, which largely comprises the Fynbos biome is the most heavily invaded, particularly by woody shrubs and trees. This is followed by Mpumalanga, KwaZulu-Natal and the Limpopo Province. The largest total invader-transformed areas are those invaded by species of *Racosperma* Mart. (wattles), *Pinus* L. (pines) and *Prosopis* L., and *Lantana camara* L. These invasions deplete water resources (particularly woody invaders), affect delivery of ecosystem goods and services, over-utilise or alter natural resources (e.g. nitrogen addition), shift (often intensify) fire regimes, and affect sand movement and salt concentration (Richardson & Van Wilgen, 2004). Other effects include poisoning, for example *Bryophyllum delagoense* (Eckl. & Zeyh.) Schinz (Fig. 13) (= *B. tubiflorum* Harv.) and *B. pinnatum* (Lam.) Oken, succulent members of the Crassulaceae, which are both poisonous when ingested and cause heart failure. The flowers are five times more poisonous than the leaves and the poison can accumulate in body tissue. The impacts are primarily on livestock (Naughton & Bourke, 2005). To date no investigations have been done to measure the impacts of these two alien crassuloid species on the native flora and fauna.

Fig. 13. Ingestion by livestock of the flowers and leaves of *Bryophyllum delagoense* (Eckl. & Zeyh.) Schinz can lead to death by poisoning. (Picture by Geoff R. Nichols)

Eradication and control of invasive plants is extremely costly. This may be done either through labour intensive manual clearing, the use of chemicals (e.g. herbicides), or by the introduction of host-specific plant-feeding insects, mites and pathogens from the invader's country of origin, i.e. the plant's natural enemy or enemies, into a new country where the plants have become problematic (biological control or biocontrol) (Zimmermann *et al*., 2004). There is a risk of biocontrols themselves becoming invasive and attacking organisms that were not intended for targeting. The use of biocontrol agents requires very careful research before they are piloted to ensure that undesirable consequences are evaluated and avoided. The price of clearing invasive species may vary depending on the density of the invasion and also on the species being cleared. It was estimated that South Africa allocated approximately R355 million to alien invasive clearing during the 2002/2003 financial year (Marais *et al*., 2004). This highlights the importance of biological control as a comparatively inexpensive and effective means of eradicating alien invasives in the medium- to long-term as the biological control agents inflict damage and cause a decline in population densities, distribution and/or rates of spread of the problem plants. This reduces the costs of other management practices (Zimmermann *et al*., 2004). A total of 111 biological control agents have been released in South Africa against 67 invasive alien plants since 1913. These include 13 succulent species. Eighty-three agents have become established on forty-seven invasive plant species in 14 families. Thirty percent of the released agents inflict extensive damage to the weeds, including 11 succulents. Twenty-five percent resulted in considerable damage and 20% cause a moderate degree of damage to their target hosts (Klein, 2011). Targeting emerging weeds for biological control at an early stage of invasion could considerably increase the chances of success (Olckers, 2004). Preference for biological control agents is also highlighted by the adverse effects of chemical control. The side-effects and impacts on non-target species of the chemical control operations used against prickly pear, jointed cactus and other invasive cacti, for example, were severe. Arsenic pentoxide (sodium of arsenite) was widely distributed to farmers for the control of these cacti between 1893 and 1910. About 425+ tons of arsenic of soda were sold or issued to farmers in the Eastern Cape (Van Sittert, 2002). This most virulent poison was potentially as lethal to farmers' lands, livestock and labourers as it was to the targeted cacti. It caused considerable damage to thorn trees, shrubs, and herbage, as well as the health of livestock and humans while the overall hidden costs were high. Areas of spillage in the natural vegetation were free of all vegetation for more than forty years (Zimmermann, *pers. obs*.). Although the hormone weed killer (2,4,5-T diluted in illuminating paraffin) was less toxic to mammals, it was a potent tree and shrub killer. Between 1958 and 1979, 107 million litres of ready mix herbicide was distributed to farmers for the control of mainly jointed cactus (Moran & Annecke, 1979). This herbicide was later replaced by water based MSMA (Monosodium Methanearsonate, an organic arsenate) which was more selective and caused less harm to the environment. It was issued to landholders on a subsidised basis. Herbicide-dominated eradication of prickly pear took place during 1893 to 1930. Herbicide usage then shifted to jointed cactus between the years 1957 to about 1999 when full reliance was placed on biological control. The farmers were then issued with cochineal instead of herbicide to control the jointed cactus. During the 1970's considerable volumes of herbicides were also issued for the chemical control of the chain fruit cholla (*Cylindropuntia fulgida*). Recently, all support for the chemical control of this most vicious cactus was terminated when a highly successful biological control programme was launched.

3. History of invasive succulent plants in the region

by Helmuth G. Zimmermann

About 55% of all listed invasive plant species in South Africa are of horticultural origin. This is considerably more than the 6%, 11% and 13% that were introduced for forestry, agriculture and as barrier plants respectively (H. Klein, *pers. comm.*). Except for two *Agave* species, a *Furcraea* species (Fig. 14) and two *Opuntia* species (Fig. 15) practically all (about 300–400 species) of the introduced succulents came into the country as ornamentals. There are also a few that arrived in South Africa unintentionally. Presently there are only 24 succulent species on the CARA list (version 6 of 2007) of declared invasive plants. This figure is low compared to the many species that are now naturalised or widely cultivated as ornamentals. Certainly there must be some “sleeper” weeds amongst these that will become invasive in the years to come. Amongst these are several representatives of the Cactaceae, Crassulacaeae, Euphorbiaceae and other families. It is vitally important to identify these potential new invaders at an early stage and to prevent them from reaching harmful population numbers, in addition to preventing the introduction of new potentially harmful species. All these species need to be subjected to detailed risk analyses, which is now a new emerging science in botany (Richardson & Van Wilgen, 2004).

Fig. 14. *Furcraea foetida* (L.) Haw. was introduced into South Africa as a commercial fibre crop, but has escaped into natural vegetation. (Picture by Neil R. Crouch)

Fig. 15. *Opuntia robusta* Pfeiff. was introduced into South Africa as a fodder plant. (Picture by Gideon F. Smith)

According to Glen (2002) there are no less than 183 species in the Cactaceae that are cultivated in South Africa, while some succulent nurseries suggest that this figure is probably closer to 250 species. Except for *Rhipsalis baccifera* (J. Mill.) Stearn subsp. *mauritiana* (DC.) Barthlott (Fig. 16), an epiphyte, all species in the Cactaceae are alien to South Africa. Amongst the many introduced genera there are only a few that include species which have consistently shown tendencies to become invasive, such as *Opuntia*, *Cylindropuntia*, *Cereus* Mill., *Cleistocactus* Lem., *Harrisia* Britton, *Pereskia* Mill. and *Tephrocactus* Lem. Similar patterns are seen in Australia (J.R. Hosking, *pers. comm*.). Amongst the Crassulaceae, the genera *Kalanchoe* Adans. and *Bryophyllum* Salisb. could be identified as posing a threat to our environment because of the large number of species in these genera which show strong tendencies towards invasiveness. In contrast there are no indications, yet, of invasiveness in the genera *Sedum* L. and *Echeveria* DC. with more than 25 widely cultivated species recorded as occurring in South Africa. It is disconcerting that there are 61 and 7 species, respectively, in these two genera recorded as weedy in the Global Compendium of Weeds (Randall, 2010). It is highly probable that from amongst this pool new invasive succulents will emerge.

Fig. 16. *Rhipsalis baccifera* (J. Mill.) Stearn subsp. *mauritiana* (DC.) Barthlott is the only cactus indigenous to South Africa, indeed to Africa. (Picture by Neil R. Crouch)

Species in the genera *Opuntia* and *Cylindropuntia* stand out as being notoriously invasive not only in South Africa, but also in many other countries (Zimmermann *et al*., 2009). They all share certain characteristics which include heavy fruiting, vegetative reproduction, spines, good dispersal mechanisms and lack of natural enemies because of their taxonomic isolation. Not surprisingly it is now virtually impossible to obtain import permits for any species in these genera. The problems concerning Opuntieae are exacerbated where certain spineless cultivars of *O. ficus-indica* (L.) Mill. and O. *robusta* Pfeiff. are permitted because of their agricultural importance as fruit and fodder plants. These spineless cultivars are mutations which are then cloned and used for cultivation. Unfortunately with genetic recombination both species have reverted back to their wild spiny forms (Fig. 17, 18) which then become invasive. In the case of *O. ficus-indica,* this has resulted in a conflict of interest where some encourage and promote the species (spineless form) while others control and try to eradicate the same species (spiny form) (Beinart, 2003). This has serious legal implications as well as restricting the use of biological control which is often the only reasonable option. Resolving such conflicts of interest is difficult (Annecke & Moran, 1978; Middleton, 1999). *Cereus jamacaru* DC. is an aggressive invader in South Africa. In Israel, a member of the *C. hexagonus* complex referred to as *C. peruvianus* (Nerd *et al*., 2002) is cultivated for its fruit. This must be either *C. hildmannianus* or *C. jamacaru*, and it may be only a matter of time before selected cultivars are cultivated in South Africa giving rise to another potential conflict of interest issue.

Fig. 17. *Opuntia ficus-indica* (L.) Mill. plants reverting to the spiny form.
(Picture by Pieter J.D. Winter)

Fig. 18. *Opuntia robusta* Pfeiff. plants reverting to the spiny form.
(Picture by Helmuth G. Zimmermann)

There are several potentially invasive alien succulents sold in nurseries as "sterile" cultivars, for example *Kalanchoe* selections and some *Echeveria* hybrids. This is certainly an option to lower the risk for unintentional invasions provided that the risk for reversion back to the wild forms is minimal. The cooperation of the nursery industry in determining these risks is vital. The Nursery Partnership Programme is aimed at minimizing the risk of releasing potentially invasive ornamentals into the environment. The so-called sterility of cultivars remain open to conjecture though.

Unlike other non-succulent invasive species e.g. in the genera *Campuloclinium* DC. and *Parthenium* L., succulents have generally a long lag phase before becoming invasive. It took close to 150 years for *Opuntia ficus-indica* to reach population levels which became harmful (Annecke & Moran, 1978; Von Sittert, 2002). *Opuntia aurantiaca* was introduced as an ornamental in 1843 but the first records of harmful invasions date from the 1890s (Moran & Annecke, 1979). The lag phase for *Harrisia martinii* (Labour) Britton (Fig. 19) and *Cereus jamacaru*

(Fig. 20) could be around 60 and 40 years respectively (Moran & Zimmermann, 1991a). *Agave americana* L. (Fig. 21) was deliberately introduced and cultivated in the Graaff-Reinet area in about 1850 but the plant has only been added to the CARA list as recently as 1980 (Henderson, 2001). Species with a long lag phase are particularly amenable for the early detection and rapid response programme which was recently launched in South Africa. Other succulent invaders, however, with a short lag phase are amongst the most aggressive species. The chain fruit cholla, *Cylindropuntia fulgida,* was first recorded in South Africa in the 1940s and extensive infestations were already present in the Douglas area during the 1960s. Despite intensive eradication programmes initiated by the Department of Agriculture in the early 1970s, the cactus continued to spread and develop dense populations. Other species in the genus *Cylindropuntia* show very similar tendencies. Unfortunately they are still sold by uninformed nurseries and are common rockery plants.

Fig. 19. *Harrisia martinii* (Labour) Britton had a lag phase of 60 years before it became a problem plant. (Picture by Gideon F. Smith)

Fig. 20. *Cereus jamacaru* DC. had a lag phase of 40 years before it became a problem plant. (Picture by Helmuth G. Zimmermann)

Fig. 21. *Agave americana* L. subsp. *americana* growing near Graaff-Reinet. Plants were introduced to that district in about 1850. (Picture by Neil R. Crouch)

4. Legislation and control programmes to manage unwanted invasions

by Helmuth G. Zimmermann

Nowadays virtually all countries have legislation to prevent the introduction and aid the control and management of unwanted species that impact negatively on agriculture and the environment. Invasive alien cacti in particular, are amongst the organisms that have had the most severe effects on agriculture in South Africa dating back almost 150 years. Legislation dealing with alien plants falls into two categories: (1) Acts that prevent the introduction of potentially invasive alien species into the country and (2) Acts that deal with the management and control of invasive alien plants already established in the country.

4.1. Acts that prevent introduction

There was no legislation prior to 1911 that prevented or controlled the introduction of unwanted organisms into South Africa. Several events or periods between 1652 and 1911 can be identified that were responsible for the introduction of many alien plant invaders. These events are well described by Wells *et al.* (1986). It was during this period, spanning 250 years, that many important cactus and at least one *Agave* species were deliberately introduced as part of the attempts of the European colonists and colonial rulers to "beautify" the colony and to establish new and useful plants species wherever possible. Annecke & Moran (1976), Moran & Annecke (1978) and Van Sittert (2002) give detailed accounts of the introduction and spread of prickly pear (*Opuntia ficus-indica*) and *O. aurantiaca,* the two alien weeds that have impacted greatly on the lives of humans and animals in the Western, Eastern and Northern Cape Provinces. The efforts are well known and documented, of individuals, like Baron Carl Ferdinand Heinrich von Ludwig (1784–1847) who resided in Cape Town and played a key role in receiving exotic plants from contacts in India, Europe and, in particular, Great Britain (often in exchange for members of the Cape flora) (Moran & Annecke, 1978). He has been credited with introducing *Cereus*, *Opuntia aurantiaca* and other *Opuntia* species (Bradlow, 1965). L.W. Sammons reports in Sam Sly's Journal dated October 1843 (see Moran & Annecke, 1978) that "the finest collection in this Colony of Mammillarias, Echinocacti, Cereus – Melocactus, Opuntia etc. lately arrived in Cape Town in the *Bosphorus* from England". The account also mentioned that plants for the Baron came mainly from the estates of Woburn Abbey and Chatsworth, and from the botanical gardens at Kew, Glasgow and Edinburgh. Woburn Abbey was known to have "the finest cactus collections in England". Forbes (1837) lists 315 species of cacti in the collection, including 81 species of *Opuntia* and *O. aurantiaca* is specifically mentioned. Other records of plant exchanges between the Baron and other famous gardens in Britain, e.g. Chiswick Gardens, that were "over-flowing with orchards and cacti" according to Fletcher (cited in Moran & Annecke, 1978), have been recorded. There is thus circumstantial evidence that *Opuntia aurantiaca* (and probably other cacti) arrived in Cape Town perhaps during 1843 and was passed on from the Ludwig's garden to the Cape Town Botanical Garden (not to be confused with the Kirstenbosch National Botanic Garden) between 1848 and

1858. The curator of the garden, J. McGibbon was in touch with missionaries who were often interested in botany and introducing new crops and novelties to their remote mission stations. Strange looking succulents were certainly novelty plants that have attracted much attention.

Text Box 2. Prominent legislation dealing with alien plants in South Africa.

DCA: The Divisional Council Act No. 40 of 1889
APA: Agricultural Pest Act No. 11 of 1911
The Cape Provincial Council Ordinance No. 18 of 1928
The Jointed Cactus Eradication Act No. 52 of 1934
The Weeds Act No. 42 of 1937
The Soil Conservation Act No. 76 of 1969
APA: Agricultural Pest Act No. 3 of 1973
APA: Agricultural Pest Act No. 36 of 1983
CARA: Conservation of Agricultural Resources Act No. 43 of 1983
ECA: The Environment Conservation Act No. 73 of 1998
NEMA: The National Environmental Management Act No. 107 of 1998
NEMBA: The National Environmental Management: Biodiversity Act No.10 of 2004

In summary it can be assumed that many cacti and other succulents from the New World were already introduced and established in South Africa by 1911 and that the spread of two of these, *Opuntia aurantiaca* and *O. ficus-indica,* had already reached alarming proportions in the Eastern Cape which urgently warranted control measures.

The first Agricultural Pest Act (APA), No. 11 was promulgated in 1911 and was aimed primarily at preventing the introduction of agricultural pests. Plants could only be imported into the country under the authority of a permit. The Act also provided special powers to control and eradicate pests of national importance affecting agriculture e.g. locusts. The emphasis was on crop security and protecting agricultural production. By this time the then Cape Province (now the Western, Eastern and Northern Cape Provinces) already had a history of almost 60 years of trying to cope with the serious invasions of prickly pear and jointed cactus and Government officials were sensitised towards other potentially dangerous invasive cacti in general. It would therefore have been difficult to legally introduce further jointed cactus-type plants. This Act was later replaced by the APA, Act 3 of 1973 and later by the APA, Act 36 of 1983 (with at least five amendments) which continued to regulate the importation of all “controlled goods” including plants. Species for introduction are subjected to pre-border and post-border weed risk assessments following guidelines provided by the International Plant Protection Convention (IPPC) (FAO, 2006). As with the previous Act, the emphasis was on protecting agriculture.

It was only after the Convention on Biological Diversity (CBD) was ratified in 1995 that new legislation controlling the importation of potentially invasive species was considered. There are three Acts, all mandated by the Department of Environmental Affairs, that affect the introduction and management of invasive alien species in some or other way with the emphasis on protecting the environment and biodiversity. These are (1) The Environment Conservation Act No. 73 of 1998 (ECA); (2) The National Environmental Management Act No. 107 of 1998 (NEMA) and; (3) The National Environmental Management: Biodiversity Act No.10 of 2004 (NEMBA). Chapter 5 of NEMBA deals specifically and comprehensively with the introduction and management of invasive alien species. The Regulations regarding established plants are based on lists that are divided into specific categories, each with its own particular management prescriptions. These lists match similar lists published under the Conservation of Agricultural Resources Act (CARA). Legal action and financial support to control invasive plants is only possible once a species has been listed. The NEMBA regulations, however, also provide for emergency interventions and for an early detection and rapid response programme to deal with new and emerging issues. New introductions of alien organisms can only occur under the authority of a permit after subjecting the species to an initial and/or a comprehensive risk assessment process. Harmonization between NEMBA and the two agricultural Acts (APA and CARA) regarding invasive plants is required. The environmental Acts are implemented mainly at provincial level while the agricultural Acts are implemented nationally. Two import permits from two different Government Departments will therefore be required in future, based on separate risk assessments, to introduce new ornamental succulents into South Africa.

The control of imported seeds through the postal services remains a challenge though. All seeds of ornamental cacti and many other succulents are small and can easily be sent by conventional air or surface mail. This challenge is compounded by the easy access to seeds through the internet trade.

4.2. Acts that deal with the management and control of invasive plants

There were a few Acts in place during the late nineteenth century that focused specifically on the control of three weeds. These were *Xanthium spinosum* L., *Opuntia aurantiaca* and *O ficus-indica.* Until 1911 *Opuntia ficus-indica* was undoubtedly the plant invader that had had the greatest impact on agriculture and the environment but it was never included in any Act that would assist in its management and control at a national (Cape Colony) level. The reason for this was the conflict of interest amongst landholders regarding the dangers and benefits of prickly pear. The farmers north of the Winterberg/Amatola line could benefit from the prickly pear because the plant was considerably less invasive in the climatically severe, and much colder Upper Karoo while severe invasions occurred south of this line. Until this day there has never been a weed that has generated so many discussions and produced so many reports as the prickly pear. The history of the introduction, invasion, impact and control of prickly pear in South Africa, and the conflicts around its weed status have been documented in detail by Annecke & Moran (1978), Beinart (2003) and Van Sittert (2002). No other plant has contributed more to creating a general awareness concerning the dangers of invasive plants, in particular the dangers of exotic cacti in this country.

Despite several efforts to pass a national law to enforce control measures for prickly pear, during the late nineteenth and early twentieth centuries, this never materialised. The last attempts occurred in 1906 but as in previous cases, the Director of Agriculture again refused to authorise a Prickly Pear Act on grounds that “it would be a hardship to (some) farmers and unfair towards the general taxpayer”. Instead, the responsibility for control of prickly pears was devolved to local authorities such as the Divisional Councils. The 1889 Divisional Council Act (amended twice between 1889 and 1910) catered primarily for *Xanthium spinosum* but ignored prickly pear except in two districts where it was proclaimed a noxious weed. The Acts were toothless, were not backed with adequate finances to implement them, had limited powers and contributed little towards solving the prickly pear problem.

There was, however, no conflict of interest with jointed cactus, *Opuntia aurantiaca,* and expensive programmes were put in place to control this plant. The promulgation of the Cape Provincial Council Ordinance No. 18 of 1928 made the control of jointed cactus compulsory. This was followed by the more powerful Act No. 52 of 1934, the Jointed Cactus Eradication Act which placed the responsibility for control on the State Department of Agriculture. Under this Act teams of departmental labourers were employed to assist in the mechanical and chemical control of jointed cactus (Moran & Annecke, 1978; Pettey, 1948). This Act was eventually replaced by the Weeds Act of 1937 which continued to make State subsidies available for the control of mainly jointed cactus. A new subsidy scheme was put in place in 1957 to chemically control jointed cactus, prickly pear, imbricate cactus and chainfruit cholla (previously known as the rosea cactus) and later also other declared invaders e.g. nassella tussock grass. The subsidy scheme was later managed under the Soil Conservation Act of 1969. Eventually the Weeds and the Soil Conservation Acts were replaced by the Conservation of Agricultural Resources Act, better known as CARA (Act No. 43 of 1983) which continued with the subsidy schemes until 1999 when the Working for Water programme took over many of the initiatives on invasive plant control, including those on the invasive cacti.

The objectives of CARA were, *inter alia*, “the protection of the vegetation and the combating of weeds and invader plants”. However, this role was to a large extent taken over by NEMBA which purports to “manage and control invasive species to prevent or minimise harm to the environment and biological diversity, and in particular where possible and appropriate, eradicate invasive species that may cause such harm”. These two Acts do not only share the same objectives but also share similar lists of invasive alien plants that are declared and subjected to specific control measures. In order to take any action against any invasive plant species it must be listed and must fall into one of three or five categories respectively. The CARA list contains 198 species divided into three categories, each one with its own control and management prescriptions. There are 24 succulent species listed in CARA (version 6 of 2007), 17 of them belonging to the family Cactaceae. The proposed NEMBA list will have close to 345 species divided into five categories. There are over 30 succulent species in this list, 16 of them being cacti. A revised CARA list will reflect the same species and categories.

4.3. Control programmes

Historically, several national campaigns aimed at the control of some cactus and other invaders have been implemented in South Africa. Some date back to the late 19th century when mechanical clearing of invasive prickly pear in the eastern Cape Colony was instigated by the Cape colonial government sometime after 1883 (Annecke & Moran, 1976). This campaign was unsuccessful and was replaced by chemical control based on using a highly poisonous arsenic-based herbicide (arsenite of soda) which remained in use for some 50 years, against both prickly pear and jointed cactus. The environmental impact of this highly toxic compound on plants, animals and humans was horrendous (Van Sittert, 2002). Biological control followed which was shown to be most successful when a cochineal insect, *Dactylopius ceylonicus*, was obtained from India in 1913 which controlled the cactus weed, *Opuntia monacantha* Haw., along the southern coast of South Africa (Fig. 22). This, accompanied by the success of the biological control of *O. stricta* in Australia and supported by public pressure to act on the threat posed by *O. ficus-indica* and *O. aurantiaca*, convinced the minister of Agriculture of that time to embark on a biological control campaign which lasted for thirty years. Two natural insect enemies, the cactus moth, *Cactoblastis cactorum* and the cochineal, *Dactylopius opuntiae*, were introduced in the thirties to control prickly pear and, assisted by hand felling of infested plants, eventually cleared about 80% of the infestations by the late 1950s (Annecke & Moran, 1978). There was a strong lobby of Karoo farmers at the time that vehemently opposed biological control, contributing to a debate which continues to this day (Beinart, 2003). Fortunately it is still possible to successfully cultivate the commercial varieties of prickly pear despite the presence of the two biological control agents that are now regarded as pests in plantations and orchards. A similar successful campaign was also launched at about the same time against jointed cactus, *O. aurantiaca,* using another host-specific cochineal species, *Dactylopius austrinus* originally from Argentina, and introduced from Australia in 1935 (Moran & Annecke, 1978). The introduction of yet another cochineal, *D. tomentosus*, in 1958 for the control of the imbricate cactus, *Cylindropuntia imbricata,* and *C. leptocaulis,* followed (Moran & Zimmermann, 1991a). Recently, equally successful, biological control projects were launched against *Opuntia stricta* and *Cylindropuntia fulgida* using host-specific selected biotypes of *Dactylopius opuntiae* and *D. tomentosa,* respectively (Paterson *et al*., 2011; Zimmermann *et al*., 2004). The cactus mealybug, *Hypogeococcus pungens* (also known as *H. festerianus*), was also successful in controlling rampant invasions of *Harrisia martinii* and *Cereus jamacaru* in the 1980s and 1990s. Other biological control projects implemented against other succulent cacti, however, were less successful, for example *Pereskia aculeata* (Klein, 1999). In general, the track record of biological control against invasive cacti in South Africa is exceptionally good compared to attempts to control invasive representatives of other plant families in the same way. This is partly because of the host specificity of the cactus-feeding natural enemies as well as the fact that, with the exception of a single species of *Rhipsalis* Gaertn., Africa is void of native species in this rather unique family of plants, allowing for a larger selection of host-specific insects to be used.

Fig. 22. About 100 years ago populations of *Opuntia monacantha* Haw. were biologically controlled by releasing a cochineal insect on them. (Picture by Helmuth G. Zimmermann)

Chemical control, using the highly toxic inorganic sodium of arsenite, was the only method available to kill invasive cacti for many years. Since 1957 a new hormone herbicide, 2,4,5-T diluted in illuminating paraffin was supplied to landholders gratis, provided that they used their own labour to treat the cacti. This scheme was primarily aimed at the control of jointed cactus but was later also used against other invasive cacti. 2,4,5-T was later replaced by Picloram which showed serious non-target effects because of the tendency of jointed cactus to grow under trees which are highly sensitive to this product. Currently another herbicide, namely an organic arsenate product, MSMA (monosodium methanearsonate) is registered for the control of cacti (Anonymous, 2004). Most succulents, and in particular cacti and *Agave* species, are very sensitive to any arsenical-based herbicide. MSMA which is relatively less expensive and considerably less toxic than the inorganic arsenites, is effective against all invasive cacti and has less non-target effects on other vegetation. Stem succulents such as prickly pear, *O. stricta* and *Agave* species, are effectively controlled with stem injections of small quantities of MSMA (Zimmermann, 1989). A second, but less effective, herbicide, namely glyphosate, is also registered for the control of some cacti but was never made available in any subsidy scheme.

4.4. Nursery Partnership Programme

Nurseries have been the origin and point of distribution of many invasive plant species in South Africa. There are well over 250 species of cacti, *Agave* and non-native, succulent and non-succulent *Euphorbia* L. cultivated in South Africa (Glen, 2002) most of which are found in, or originated from, the nursery trade (Fig. 23). Fortunately very few of these species show tendencies to naturalise or become invasive. Deliberate introductions by Botanical Gardens and Government departments also provided their share of invasives. It is a formidable but essential task to identify species at an early stage of invasion and then to take quick action. The Nursery Partnership Programme aims to do this by preventing the sale of potentially invasive species. It remains the State's duty to, firstly, prevent the introduction of potentially invasive succulents and secondly, to identify dangerous species already in the country that have the potential to become invasive and then to take quick action. The cooperation of the nurseries is essential in achieving this goal. CARA provides a list of "emerging species" that show tendencies towards invasiveness but which still lack the evidence to be categorised. Some of these species are still found in the nursery trade. The ideal is to convince all nurseries to join the South African Nursery Association (SANA) and to adhere to a code of conduct. Unfortunately there are still far too many nurseries that trade in listed and emerging species and the regulatory arm of the Government is not able to prevent this.

Fig. 23. A wide variety of cactus species are offered for sale in the nursery trade. Some of these may eventually become problematic. (Picture by Helmuth G. Zimmermann)

4.5. Early detection and rapid response programme

"Prevention is better than cure" and this is certainly the case for invasive alien species. It makes economic sense to deal with invasions at an early stage before they are out of control and when they can still be eradicated or contained. Considerable know-how and experience is required to identify those potentially aggressive invaders amongst hundreds of exotic succulent species in cultivation, that could justify a rapid response programme. These decisions are based on detailed risk assessment analyses which are supposed to predict the aggressiveness of an invader. Such an early detection and rapid response programme has recently been launched in South Africa managed by the South African National Biodiversity Institute (SANBI) supported by the Working for Water Programme. Since the inception of the project several new succulents e.g. *Bryophyllum pinnatum* (Fig. 24), *Cylindropuntia fulgida* var. *mamillata, Tephrocactus articulatus* (Pfeiff.) Backeb., *Opuntia salmiana* J.Parm. ex Pfeiff. and *Harrisia balansae* (K.Schum.) N.P.Taylor & Zappi have been identified and are now being targeted for rapid response actions. The Programme relies heavily on the experiences of other countries with similar climates, e.g. Australia, and on the participation of "spotters", the SAPIA programme and interested stakeholders to identify new invaders at an early stage of establishment.

Fig. 24. *Bryophyllum pinnatum* (Lam.) Oken has recently become a pest plant in South Africa. (Picture by Neil R. Crouch)

5. Collecting succulent plants for deposition in a herbarium

by M. Walters

5.1. What is a plant specimen?

A preserved plant specimen is a dried and mounted or pickled voucher that is the botanical world's equivalent to the zoologist's stuffed animals, skins or insect collections that are kept in natural history museums (Fig. 25). Plant specimens are housed in herbaria which are permanent repositories of specimen collections and their associated data.

Fig. 25. A preserved specimen of an indigenous succulent, *Aloe arborescens* Mill., kept in the National Herbarium of South Africa (PRE). (Picture by SANBI)

5.2. How are plant specimens useful?

Herbarium specimens in the vast collections held by Herbaria all around the world are extremely valuable for a number of reasons. Not only are specimens useful when trying to identify plant material, they also provide a record of where and when a particular species was found growing. The information that can be found on the specimen label is valuable too, and may give clues as to, for instance, soil substrate the plant was found growing in. As classifying plants is not a static process, and plant names may therefore change as species concepts change or as new evidence for re-classification is found, specimens can be used to verify past identifications. Label information on herbarium specimens is also used as a way of determining the area of occupancy (AOO) of species, which is an important parameter to determine their conservation status (Red List status) (Hernández & Navarro, 2007). This method results in more accurate, less overestimated determinations of AOO, and will as a result produce more useful and valuable Red List assessments.

5.3. Why bother collecting voucher specimens for exotics?

There are many more ways in which specimen collections are useful, but as far as alien plants are concerned, physical specimens can be of particular use, when investigating points of entry and range expansion of these species over time. They also aid in the development of predictive habitat models that may give clues about habitat preference and potential for future spread.

Most people know better than to touch a cactus with their bare hands. The spines and fine glochids, in the case of representatives of *Opuntia* (prickly pears) and their relatives, found on most species can be very irritating and quite painful when lodged under the skin. So when appeals are made for collecting and pressing these plants, a general lack of enthusiasm is usually shown by professional botanists and by the public alike. Preparing preserved specimens of these plants with their unwelcoming, prickly habit may seem like more effort than it is worth. For this reason, cacti are often not collected and are thus poorly represented in herbaria (Leuenberger, 1987). This is particularly true for southern Africa where, except for one species (*Rhipsalis baccifera* subsp. *mauritiana*), cacti do not comprise part of the indigenous flora and are thus mostly ignored, even by environmental consultants and other specialist collectors. Unfortunately, because of this, potentially valuable information about these plants does not reach the people responsible for monitoring and controlling their spread. The collection of herbarium specimens greatly enhances the quality of invasions biology as a whole by providing study material for current and future studies (Carter *et al*., 2007).

5.4. How to contribute to expanding herbarium plant collections

A basic 3-step process is followed to prepare useful herbarium specimens.

1. Collecting (Fig. 26)
2. Preparation and pressing (Fig. 27)
3. Identification and mounting

5.4.1. Collecting

Selecting the material

When selecting plants for pressing it is important to bear in mind that it is preferable for specimens to have flowers and/or fruit included to aid identification (Leuenberger, 1987; Victor *et al*., 2004). A specimen consisting of sterile material accompanied by the correct information, however, is better than nothing and may be useful in providing pieces of the puzzle for a taxon as a whole. A specimen of, for example, an exotic plant should therefore be made regardless of whether the plant is flowering or not. Adding an illustration (drawing, photograph, print of an electronic image) to the specimen can considerably enhance its value.

In the case of smaller plants, it is best to collect the entire plant, including underground parts, while for larger plants, representative parts should be collected. These should include mature and immature parts, lower and upper leaves, buds and coppice shoots (Victor *et al*., 2004).

Collecting

Once you have selected a plant it is best to place it in a plant press immediately or, if that is not possible, in paper bags. The use of plastic bags is discouraged as it causes sweating in succulent plants, which results in the formation of mould (Burgoyne & Smith, 1998). Large specimens can be bent or cut before placing them in a press. In the case of fat-bodied plants such as cacti, both longitudinal and cross-sections should ideally be prepared, pressed and dried. Care should be taken when working with spiny plants and it is advisable to wear protective gloves. Some plants (like those in the Euphorbiaceae) contain irritant plant sap and contact with the skin, mucous membranes and particularly the eyes should be avoided.

Fruits and flowers, as mentioned, are often critical for correctly identifying plants. This is particularly true for many cactus species, where dissection of the flowers or fruits facilitates correct identification. It is therefore often useful, not only to press, but also to collect whole fruits and flowers. These may be preserved —pickled— in jars with 50–70% diluted ethanol (Leuenberger, 1987).

To prevent the further spread of exotic plants, special care should be taken that no seeds or reproductive parts of the plant is dispersed during and after collecting (Carter *et al*., 2007). This means not only the careful checking of equipment but also clothing and the bottoms of shoes, shoe laces and especially any velcro.

Auxiliary information

Ideally a specimen should be accompanied by photographs of the plant while still growing in its natural habitat. These are valuable complimentary identification tools that provide information on habit or other characters not always visible on dried, preserved specimens (Leuenberger, 1987).

Fig. 26. Collecting plant material for deposition in a herbarium. (Picture by SANBI)

Other relevant data should also be recorded on field labels, in collecting books or in portable electronic data-capturing devices, where possible. Essential information includes: Name of collector, date of collection and where it was collected (with map or GPS coordinates). Other useful information includes: altitude, aspect, vegetation type, geology, soil type, abundance (frequent or rare), plant size and height, stem diameter as well as details that may be lost upon drying, such as flower or fruit colour, presence and colour of sap or latex and scent (Victor *et al*., 2004). It is not always possible to collect all this information but at the very least where, when and by whom the plant was collected should be recorded.

5.4.2. Preparation and pressing

While preparing a specimen of a herbaceous plant is reasonably straightforward, the same is not true for succulents, which are often bulky specimens. For a specimen of a succulent to be useful to taxonomists and other researchers it has to be handled and pressed correctly (Bridson & Forman, 1998; Victor *et al*., 2004). Unlike other plants, many succulents have to be treated before pressing (Smith, 1991; Eggli & Leuenberger, 1996; Burgoyne & Smith, 1998).

After collecting, field presses and/or paper bags containing succulents should be put in a freezer at c. -4°C for 24 hours (smaller plants require less time in the freezer) (Leuenberger, 1982; Burgoyne & Smith, 1998, and references therein).

The specimens should then be placed in a microwave for a period of 1–5 minutes (depending on the size of the specimen), a few at a time (though bundles should not exceed 50 mm in thickness), or larger plants on their own, at 80% power, which leaves them pliable and easy to manipulate (Burgoyne & Smith, 1998).

Fig. 27. Plant presses with specimens drying in the sun during a field collecting expedition. (Picture by SANBI)

Other methods for removing succulent plant tissues involve scraping out of inner plant tissues, or dipping plants in boiling water or organic liquids. The method described above, however, causes the cells to burst, allowing the resulting watery substance to simply be poured off (Burgoyne & Smith, 1998). Specimens should be removed from the microwave once they turn a dull green, at which point they are ready to be dried in a plant press. Note, however, that microwaving a specimen can yield it useless in further studies that require the removal of small sections of material for chemical or molecular analyses. The accompanying specimen label should therefore indicate whether material was microwaved. Many taxonomists actively discourage the use of a microwave oven in pre-treating specimens and prefer other less destructive methods when removing moisture from material intended for depositing in a herbarium.

Plants should be arranged in the press in such a way as to provide the most information to the user. All plant parts should be shown clearly, both sides of a leaf should be visible and the curling of leaves should be avoided. Attaching a jeweller's tag conveying the collector's name and collection number to the specimen will ensure that the specimen can eventually be associated with the correct field notes compiled by the collector.

The plant press should be packed in the correct sequence as follows (from Victor *et al*., 2004):

1. The wooden lattice frame
2. Corrugated cardboard or aluminium ventilator (corrugations run parallel to the short side)
3. Two sheets of drying paper (newspaper, cut to size, works well and is inexpensive)
4. Flimsy (thin, strong, slightly absorbent paper, such as unprinted newspaper) containing a specimen
5. Two sheets of drying paper, followed by flimsy containing a specimen
6. A ventilator after each 5–8 specimens, or after every second specimen, if the material is very bulky
7. Finish with a ventilator and the other wooden lattice frame

The drying process should not take place in too hot an environment and 45°C is considered ideal (Victor *et al*., 2004). Damp drying paper should be changed daily for about the first week after which longer intervals can be allowed, unless atmospheric humidity is very high. Damp cardboard ventilators should also be changed and care should be taken that flimsies, though not requiring changing, do not adhere to the specimens (Victor *et al*., 2004). A simple and rapid technique for drying damp newspaper flimsies and cardboard when out in the field is to spread these around on the dry ground in full sun securing them with stones. On sunny days they can be fully dried in 30 minutes or less.

5.4.3. Mounting and identification

At this point in the process specimens are usually handed over to experts as identification and mounting is done by herbarium staff. For more detailed information on the mounting of specimens please refer to Victor *et al.* (2004). Here we give a brief description of the process.

In the herbarium, the specimen is identified, a label is written, and these are then neatly arranged on a white mounting board (300–400 g and 270 × 420 mm) with the label in the lower right hand corner. Labels usually display at a minimum the unique collecting number, date and place of collection, the collector's name, the species and family names, and who determined (identified) the species. Specimens and plant parts are fixed to mounting boards with any or a combination of the following: envelopes, glue, strapping (strips of white, gummed or self-adhesive paper) or stitching.

Plant specimens may last indefinitely if they are properly prepared and cared for, kept away from water and protected against humidity and pests. In this regard it should be noted that all mounting sheets and paper used for preparing specimens and labels should be of archival quality. The same applies to the ink used for producing the labels. Each specimen is a permanent record of the occurrence of a species in time and space (Carter *et al*., 2007) and in this way immortalises the collector, who contributes to the wealth of knowledge held in herbaria to be used by future generations of plant enthusiasts (Burgoyne & Smith, 1998).

AGAVACEAE Dumort.

(Century plant family; *Garingboomfamilie*)

by

G.F. Smith

Robust, monocarpic, usually rosulate perennials arising from a short rhizome or short, erect caudex. **Stem** commonly with monocotyledonous type secondary growth. **Leaves** usually crowded in basal rosette or perched at top of stem, stiff, leathery to succulent, amplexicaul, persisting for many years, margins heavily armed or saw tooth-like; each vascular bundle with well-developed fibrous cap at phloem pole. **Inflorescence** terminal, tall, fast-growing, terminating in a panicle or spike-like panicle, often massive. **Flowers** bisexual, regular or somewhat irregular, tubular, pedicellate, 3-merous throughout. **Perianth** petaloid, 3 + 3, often fleshy, united below to form a tube. **Stamens** 3 + 3; anthers mostly dorsifixed, introrse, versatile, opening by longitudinal slits, linear to oblong. **Ovary** inferior or superior (tribe Yucceae), 3-locular, with septal nectaries; placentation axile; ovules in 2 vertical rows in each locule; style terminal; stigma 3-lobed. **Fruit** a loculicidal capsule or indehiscent berry. **Seeds** many, flattened, black.

References: Cronquist (1981), Dahlgren *et al.* (1985), Pedley & Forster (1986), Bogler & Simpson (1995), Verhoek (1998), Smith (2000), Reveal & Hodgson (2002), Smith (2003); Govaerts *et al*. (2009).

The Agavaceae (sometimes included in a broadly conceived Asparagaceae) is a medium-sized family consisting of c. 300 species of mostly leaf succulents from the New World, particularly Mexico, the southern United States of America, Caribbean Islands, Central America and northern South America (García-Mendoza, 1998). Eight genera are included in the Agavaceae: *Agave* L., *Beschorneria* Kunth, *Furcraea* Vent., *Hesperaloe* Engelm., *Manfreda* J.H.Salisb., *Polianthes* L., *Prochnyanthes* S.Watson, *Yucca* L. [including *Hesperoyucca* (Engelm.) Baker, a genus sometimes treated as monotypic].

The family is mostly adapted to desert-like conditions, and the vast majority of the species will survive under severe environmental conditions, particularly aridity and low temperatures, but they also do well in tropical and subtropical areas. Not surprisingly therefore, representatives of the family are widely naturalised in southern tropical Africa, Australia and Mediterranean Europe, among other places (Smith, 1997; Smith & Figueiredo, 2007; Smith & Van Wyk, 1999). Most species remain herbaceous, some becoming quite massive, with only a few attaining pronounced, tree-like dimensions and appearing to be 'woody'. Many representatives are rhizomatous, proliferating through basal suckers or from leaf axils (Smith, 2006b).

Flowers are tubular or campanulate, erect or dangling, lantern-like and clustered into racemes or panicles. However, in contrast to their lilioid look-alikes (for example aloes), the flowers of which all have superior ovaries, the flowers of representatives of only one group within the Agavaceae, the tribe *Yucceae*, consistently show this trait. In contrast, representatives of the tribe *Agaveae* all have inferior ovaries. Most species of the most speciose genus, *Agave*, as well as species of *Furcraea*, are monocarpic multiannuals that die after having flowered, usually after many years. However, most proliferate through basal or stem suckers, so perpetuating genetically identical offspring of the dying rosettes. These sprouts will in many instances form dense colonies that can preclude natural vegetation where they become established. Several species produce bulbils on their inflorescences, often during, but mostly immediately after, flowering is complete. These drop from the inflorescence and will easily strike root where they fall.

Much has been written about the human-agave interface, and representatives of the genus have provided an astonishing range of products that have been used since ancient times. For example, some species are useful as sources of fibre (including *Agave sisalana* Perrine and *A. fourcroydes* Lem.), while liquors such as tequila (produced from *A. tequilana* F.A.C.Weber in certain states of Mexico) and mescal are produced from others (for example *A. colorata* Gentry).

A total of eight species from two genera of the Agavaceae are naturalised in southern Africa.

Key to the two naturalised genera:

1. Flowers erect; perianth segments fused into a tube below the middle; filaments and style not swollen; bulbils plant-like. . . . . ***Agave***
1'. Flowers pendulous; perianth segments ± free; filaments swollen at base and style base dilated, bulbils globular. . . . . ***Furcraea***

Agave L.

Robust, monocarpic, usually rosulate, multi-annual perennials arising from short rhizome or short erect caudex. **Stem** commonly with monocotyledonous type secondary growth. **Leaves** usually crowded in basal rosette, leathery to succulent, amplexicaul, persisting for many years; each vascular bundle with well-developed fibrous cap at phloem pole. **Inflorescence** apical, tall, fast-growing, terminating in a panicle, often massive. **Flowers** bisexual, regular or somewhat irregular, tubular, pedicellate, 3-merous throughout. **Perianth** yellow or greenish, often with a reddish or brownish tint, petaloid, 3 + 3, often fleshy, united below to form a tube. **Stamens** 3 + 3, epipetalous; anthers mostly dorsifixed, introrse, versatile opening by longitudinal slits, linear to oblong. **Ovary** inferior, 3-locular, with septal nectaries; placentation axile; ovules in 2 vertical rows in each locule; style terminal; stigma 3-lobed. **Fruit** a loculicidal capsule. **Seeds** many, flattened, black.

References: Berger (1915), Standley (1920), Bailey (1958), Gentry (1972, 1978, 1982), Webb (1980), Espejo Serna & López-Ferrari (1993), Smith & Mössmer (1996), Irish & Irish (2000), Smith (2000), Thiede (2001), Smith (2006), Smith & Klopper (2007), Smith *et al*. (2008).

In terms of number of included species, c. 200, the genus *Agave* is the largest of the agavoid genera. *Agave* is a well known succulent plant genus of the New World being indigenous to Mexico, Central America, northern South America and the southern United States of America, as well as the West Indies. Representatives of the genus have been cultivated in southern Africa for several centuries, in both amenity and domestic horticulture. Two species have been used locally in agriculture, *Agave americana* as cattle fodder, and *A. sisalana* for fibres for use in rope making, for example.

To most people, some species of *Agave*, are best known as the source of sisal fibre and the alcoholic beverage tequila. A reversion to the beauty and practicality of natural fibres, has made carpets made from the near-indestructible sisal fibres essential products in modern interiors. On the other hand, two cocktails in particular, tequila sunrise and margaritas, of which especially the latter has produced numerous variations, contributed immensely to the current global popularity of tequila, which is essentially a type of mescal. Tequila is produced exclusively from *A. tequilana* F.A.C.Weber [nowadays sometimes referred to as *A. angustifolia* Haw. subsp. *tequilana* (F.A.C.Weber) A.G.Valenzuela-Zapata & G.P.Nabhan cultivar *azul*]. In addition, to be legally called tequila, the *Agave tequilana* 'pineapples' from which it is distilled must be harvested and produced in Mexico in one of five approved regions in the country: the entire state of Jalisco, and certain villages in the states of Nayarit, Tamaulipas, Michoacán, and Guanajuato.

Rosettes of most *Agave* species that produced a flowering pole will die. However, this does not mean the end of a specimen, as many species are proliferous through basal or stem suckers. These suckers will in many instances form dense colonies that can preclude natural vegetation where they become established. The leaves of species of *Agave* are usually crowded near the base of the plants into a sessile rosette, stiff, fleshy and armed with vicious teeth at their tips and along their margins. Smooth leaf-margined species are rare in *Agave*. In the very few species common in cultivation that have a true stem, for example *A. attenuata* Salm-Dyck, leaves are crowded near the tips of the stems.

Given that some *Agave* species are widely cultivated in southern Africa, they have been known to be problem plants locally for several decades (Wells, 1986).

Key to the *Agave* taxa naturalised in southern Africa:

1. Leaf margins devoid of teeth . . . . **5. *Agave sisalana***
1'. Leaf margins armed with small or large, sharp teeth **2**

2. Leaves distinctly light blue to glaucous green **3**
2'. Leaves light- to dark green, never blue **4**

3. Marginal leaf teeth inconspicuous, small, usually the same colour as the leaf surface . . . . **4. *Agave celsii* var. *albicans***
3'. Marginal leaf teeth prominent, usually brown **5**

4. Plants solitary . . . . **7. *Agave wercklei***
4'. Plants proliferous from the base **6**

5. Leaves often drooping to one side; plants massive . . . .**1. *Agave americana* subsp. *americana* var. *americana***

5'. Leaves erect to stiffly spreading; plants medium-sized to large . . . . **2. *Agave americana* subsp. *americana* var. *expansa***

6. Leaves dull green, armed with short, brown teeth; mid-rosette leaves spreading, closely packed on stem . . . . **3. *Agave angustifolia* var. *angustifolia***

6'. Leaves dark green, armed with prominent, greenish brown teeth; mid-rosette leaves erect, widely spaced on stem . . . . **6. *Agave vivipara* var. *vivipara***

1. *Agave americana* L. subsp*. americana* var*. americana*

In: *Species plantarum* 1: 323 (1753a).

=*Agave complicata* Trel. ex Ochot.
=*Agave felina* Trel.
=*Agave gracilispina* Engelm. ex Trel.
=*Agave melliflua* Trel.
=*Agave rasconensis* Trel.
=*Agave subzonata* Trel.
=*Agave zonata* Trel.

Common names: agave, American agave, American aloe, century plant (English); Amerikaanse aalwee, Amerikaanse aalwyn, blou-aalwee, blougaringboom, gareboom, garingboom, kaalgaarboom, makaalwyn (Afrikaans); lekhala (Sotho).

Large to massive, acaulescent or short-stemmed, monocarpic, rosulate, perennial, leaf succulent; rosettes up to 2 m tall, profusely proliferous through basal suckers. **Leaves** erect at first, becoming spreading to reflexed, flopping over to one side, lanceolate, 1–2 m long, light blue; margins armed with numerous, straight to flexuose or variously recurved, simple teeth, up to 1 cm long; apical spine conical to subulate, 3–5 cm long. **Inflorescence** paniculate, 5–9 m tall, branched, never bulbiliferous. **Flowers** erect, 7–10 cm long, yellow to greenish yellow. **Stamens** with filaments 6–9 cm long; anthers 3–3.6 cm long, centric to excentric, yellow. **Fruit** a capsule, oblong, 4–5 cm long. **Seed** lunate to lacrimiform, 7–8 × 5–6 mm, shiny black. **Distribution**: B, L, S, SA. (Fig. 28).

References: Berger (1915), Gentry (1982), Pedley & Forster (1986), Couper & Cullen (1988), Smith & Mössmer (1996).

This large, almost invariably blue-leaved century plant (Fig. 29), grows to massive dimensions and is very widespread in southern Africa. Unlike those of *Agave americana* var. *expansa*, the leaves of the typical variety usually droop to one side (Fig. 30). Several names have been applied to variants of this species, but none are nowadays upheld (see for example Ochoterana, 1913; Trelease, 1914, 1920).

It has been proposed that the species was introduced into South Africa as discarded ship's ballast, and into local horticulture as an ornamental. It spreads easily from suckers produced from the base to form large clumps. Flowers of the species are pickled and sold as a savoury delicacy (Fig. 31). Physical removal seems to be the best way of eradicating plants.

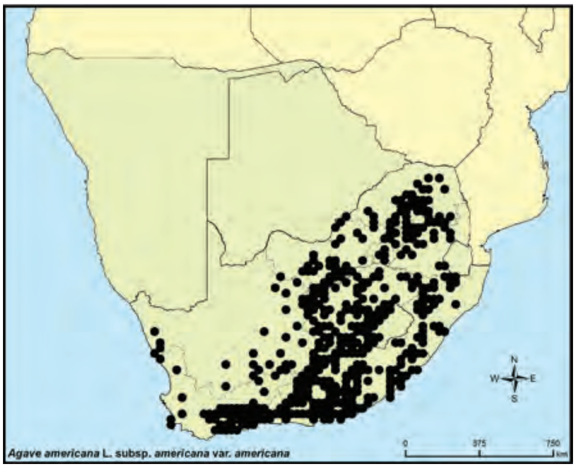


Fig. 28. Distribution map of *Agave americana* L. var. *americana.*

Fig. 29. A population of blue-leaved *Agave americana* L. var. *americana.* (Picture by Gideon F. Smith)

Fig. 30. Leaves of *Agave americana* L. var. *americana* usually droop to one side. (Picture by Neil R. Crouch)

Fig. 31. Pickled flowers of *Agave americana* L. var. *americana* are sold as a savoury delicacy. (Picture by Gideon F. Smith)

2. *Agave americana* L. subsp*. americana* var. *expansa* (Jacobi) Gentry

In: *The agave family in Sonora*, Agriculture Handbook No. 399: 80–84 (1972).

=*Agave abrupta* Trel.
=*Agave expansa* Jacobi

Common names: spreading century plant (English); skraalblougaringboom, skraalgaringboom (Afrikaans).

Large to massive, acaulescent or short-stemmed, monocarpic, rosulate, perennial, leaf succulent; rosettes up to 2 m tall, profusely proliferous through basal suckers. **Leaves** remaining erect, not spreading or reflexed, never flopping over to one side, lanceolate, 1–2 m long, light blue; margins armed with numerous, straight to flexuous or variously recurved, simple teeth, up to 1 cm long; apical spine conical to subulate, 3–5 cm long. **Inflorescence** paniculate, 5–9 m tall, branched, never bulbiliferous. **Flowers** erect, 7–10 cm long, yellow to greenish yellow. **Stamens** with filaments 6–9 cm long; anthers 3–3.6 cm long, centric to excentric yellow. **Fruit** a capsule, oblong, 4–5 cm long. **Seed** lunate to lacrimiform, 7–8 × 5–6 mm, shiny black. **Distribution**: SA. (Fig. 32).

References: Gentry (1982), Forster (1986), Irish & Irish (2000), Thiede (2001), Reveal & Hodgson (2002), Vásquez-García *et al.* (2007), Reveal & Hodgson (2009).

Unlike the typical variety of the species, the leaves of plants of *Agave americana* var. *expansa* remain erect (Fig. 33, 34) and generally have a neater appearance. However as in the case of the *Agave americana* var. *americana* the flowering pole can reach a height of 8 m (Fig. 35). It is therefore likely that *Agave americana* var. *expansa* was introduced for its greater horticultural appeal as a much tidier-looking version of the typical variety (Jacobi, 1868). This variety is known to have become established in the Western Cape Province of South Africa, where it is grown as an architectural plant in large gardens on the Cape Peninsula. It is increasingly appearing in gardens and along roadsides beyond the Mediterranean climate parts of South Africa.

Fig. 32. Distribution map of *Agave americana* var. *expansa* (Jacobi) Gentry.

Fig. 33. Leaves of *Agave americana* var. *expansa* (Jacobi) Gentry tend to remain erect. (Picture by Gideon F. Smith)

Fig. 34. Close-up of the leaves of *Agave americana* var. *expansa* (Jacobi) Gentry. (Picture by Gideon F. Smith)

Fig. 35. Inflorescence of *Agave americana* var. *expansa* (Jacobi) Gentry. (Picture by Gideon F. Smith)

3. *Agave angustifolia* Haw. var. *angustifolia*

In: *Synopsis plantarum succulentarum*: 72 (1812).

=*Agave owenii* I.M.Johnst.
=*Agave pacifica* Trel.
=*Agave yaquiana* Trel.

Common names: kleingaringboom (Afrikaans).

Medium-sized, caulescent, monocarpic, rosulate, perennial, leaf succulent; rosettes up to 1.2 m tall, proliferous through basal suckers. **Leaves** ascending to horizontal in mid-rosette, linear to narrowly lanceolate, 0.6–1.2 m long, light green to glaucous grey; margins armed with small teeth, curved or variously flexed, 2–5 mm long; apical spine conical to subulate, 1.5–3.5 cm long. **Inflorescence** paniculate, 3–5 m tall, branched, usually bulbiliferous. **Flowers** erect, 5–6.5 cm long, green to yellow. **Stamens** with filaments 3.5–4.5 cm long; anthers centric or excentric, 2–3 cm long, yellow. **Fruit** a capsule, ovoid, 3–5 cm long. **Seed** D-shaped, 9–12 × 7–8 mm, dull black. **Distribution**: SA. (Fig. 36).

References: Gentry (1982), Forster (1987–1988), Espejo Serna & Lopez-Ferrari (1993), Colunga-García Marín & May-Pat (1997), Steyn & Smith (2000).

With its fairly thin, flattish leaves densely arranged into medium-sized rosettes (Fig. 37), *Agave angustifolia* is a distinctive species that is slowly spreading into natural vegetation in South Africa. The leaves are armed with vicious marginal and terminal spines (Fig. 38). Clones established in southern Africa produce thousands of bulbils (Fig. 39) on their inflorescences (Fig. 40) and have the potential to become a real menace. Little is known about its introduction into the country.

Several names previously proposed for variants of *Agave angustifolia* are no longer upheld. Only three, *Agave pacifica* Trel., *A. yaquiana* Trel. and *A. owenii* I.M.Johnst. are listed here as possibly being applied to the species in South Africa (Trelease, 1920; Johnston, 1924).

Fig. 36. Distribution map of *Agave angustifolia* Haw.

Fig. 37. Dense, medium-sized rosettes of *Agave angustifolia* Haw.
(Picture by Geoff R. Nichols)

Fig. 38. Leaves of *Agave angustifolia* Haw. armed with spines.
(Picture by Geoff R. Nichols)

Fig. 39. Bulbils on the inflorescence of *Agave angustifolia* Haw.
(Picture by Geoff R. Nichols)

Fig. 40. Inflorescence of *Agave angustifolia* Haw. (Picture by Neil R. Crouch)

4. *Agave celsii* Hook. var. *albicans* (Jacobi) Gentry

In: *Agaves of continental North America*: 223-224, f. 9.1-9.3, 9.7, t. 9.1 (1982).

=*Agave albicans* Jacobi

Common names: vaalgaringboom (Afrikaans).

Medium-sized to large, acaulescent or short-stemmed, rosulate, leaf succulent, perennial through proliferous axillary branching; rosettes up to 0.8 m tall. **Leaves** erect at first, becoming spreading to slightly reflexed, stout, cymbiform to somewhat lanceolate, 0.4–0.6 m long, light blue; margins armed with numerous weak, straight, recurved, simple or bicuspid teeth, up to 3 mm long; apical spine obsolescent. **Inflorescence** spicate, unbranched, 1.5–2.5 m tall, never bulbiliferous. **Flowers** erectly spreading, 5–6 cm long, basal part light green, tube creamy green with metallic lavender tinge. **Stamens** with filaments 7–8 cm long; anthers centric, 2 cm long, lavender when young, yellowish when mature. **Fruit** a capsule, ovoid-angular, 1.8–2.8 cm long. **Seed** hemispherical, 5 × 3 mm, black. **Distribution**: SA. (Fig. 41).

References: Irish & Irish (2000), Smith & Steyn (2002b).

The nomenclatural history of *Agave celsii* var. *albicans* is quite complex and recently it has been suggested (see for example Thiede, 2001) that the correct name of this taxon is *Agave mitis* Mart. var. *albidior* (Salm-Dyck) Ullrich. For the moment the variety is here treated under the name proposed by Gentry (1982).

The medium-sized rosettes consisting of numerous blue-green to almost white leaves (Fig. 42), as well as the unbranched inflorescences (Fig. 43), separate the taxon from other agaves naturalised in southern Africa. It is the least noxious of the problem agaves in South Africa, and can be easily eradicated by physical removal.

The species was probably introduced as a horticultural subject, and with its interesting leaf colour it is easy to see why.

Fig. 41. Distribution map of *Agave celsii* Hook. var. *albicans* (Jacobi) Gentry.

Fig. 42. Blue-green leaved rosettes of *Agave celsii* Hook. var. *albicans* (Jacobi) Gentry develop into dense clumps. (Picture by Gideon F. Smith)

Fig. 43. Unbranched inflorescence of *Agave celsii* Hook. var. *albicans* (Jacobi) Gentry. (Picture by Gideon F. Smith)

5. *Agave sisalana* Perrine

In: United States of America 25th Congress, 2nd Session, House of Representatives Report No. 564 (Tropical Plants): 8, 9, 16, 47, 60, 86 (1838a).

Common names: hemp plant, sisal, sisal hemp (English); garingboom, sisal (Afrikaans).

Medium-sized to large, acaulescent or short-stemmed, monocarpic, rosulate, perennial, leaf succulent; rosettes up to 2 m tall; profusely proliferous through elongated rhizomes. **Leaves** erect throughout, lanceolate, 0.9–1.3 m long, dark green; margins generally lacking teeth; apical spine subulate, 2–2.5 cm long. **Inflorescence** paniculate, branched, 4–9 m tall, profusely bulbiliferous. **Flowers** erect, 5.5–6.5 cm long, greenish yellow. **Stamens** with filaments 5–6 cm long; anthers centric, 2.3–2.5 cm long, yellow. **Fruit** a capsule, generally lacking; plants sterile. **Seed** generally lacking. **Distribution**: SA. (Fig. 44).

References: Perrine (1838b), Trelease (1913), Berger (1915), Gentry (1982), Pedley & Forster (1986), Couper & Cullen (1988), Smith & Mössmer (1996).

Agave sisalana can hardly be confused with any of the other agaves naturalised or cultivated in southern Africa. The leaves are generally mid- to dark green and their margins are devoid of teeth (Fig. 45, 46).

The strong fibres extracted from the leaves of *Agave sisalana* have been widely used in weaving, and for manufacturing carpets and ropes (Fig. 47). It was therefore introduced as an agricultural crop and planted in vast numbers in plantations, particularly in areas that receive marginal rainfall (Fig. 48, 49). Once plants flower they produce thousands of bulbils (Fig. 50) on the side branches of the flowering pole, and sometimes also from the large bracts on the pole itself. These are easily transported and will strike root where they drop. These perfectly formed plantlets have been carried far and wide leading to the establishment of sparse or dense clusters of plants in many parts of the sub-region. It rates as one of the most invasive of the agaves naturalised in South Africa (Fig. 51).

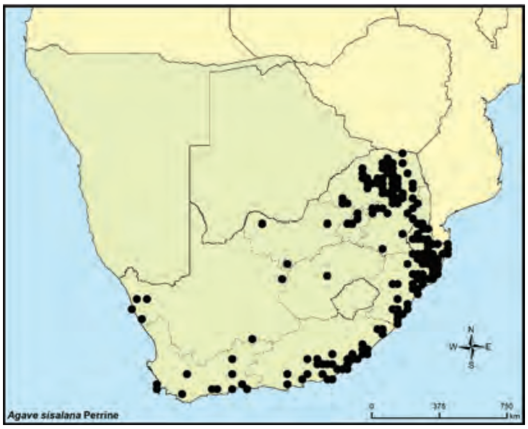


Fig. 44. Distribution map of *Agave sisalana* Perrine.

Fig. 45. Mid- to dark green leaves of *Agave sisalana* Perrine.
(Picture by Helmuth G. Zimmermann)

Fig. 46. Leaves of *Agave sisalana* Perrine do not have marginal spines. (Picture by Gideon F. Smith)

Fig. 47. Fibres of *Agave sisalana* Perrine collected for use in weaving. (Picture by Neil R. Crouch)

Fig. 48. Plantation of *Agave sisalana* Perrine from which leaves have been harvested. (Picture by Neil R. Crouch)

Fig. 49. Plantation of *Agave sisalana* Perrine. (Picture by Geoff R. Nichols)

Fig. 50. Bulbils of *Agave sisalana* Perrine
(Picture by Neil R. Crouch)

Fig. 51. *Agave sisalana* Perrine spreading into natural vegetation.
(Picture by Helmuth G. Zimmermann)