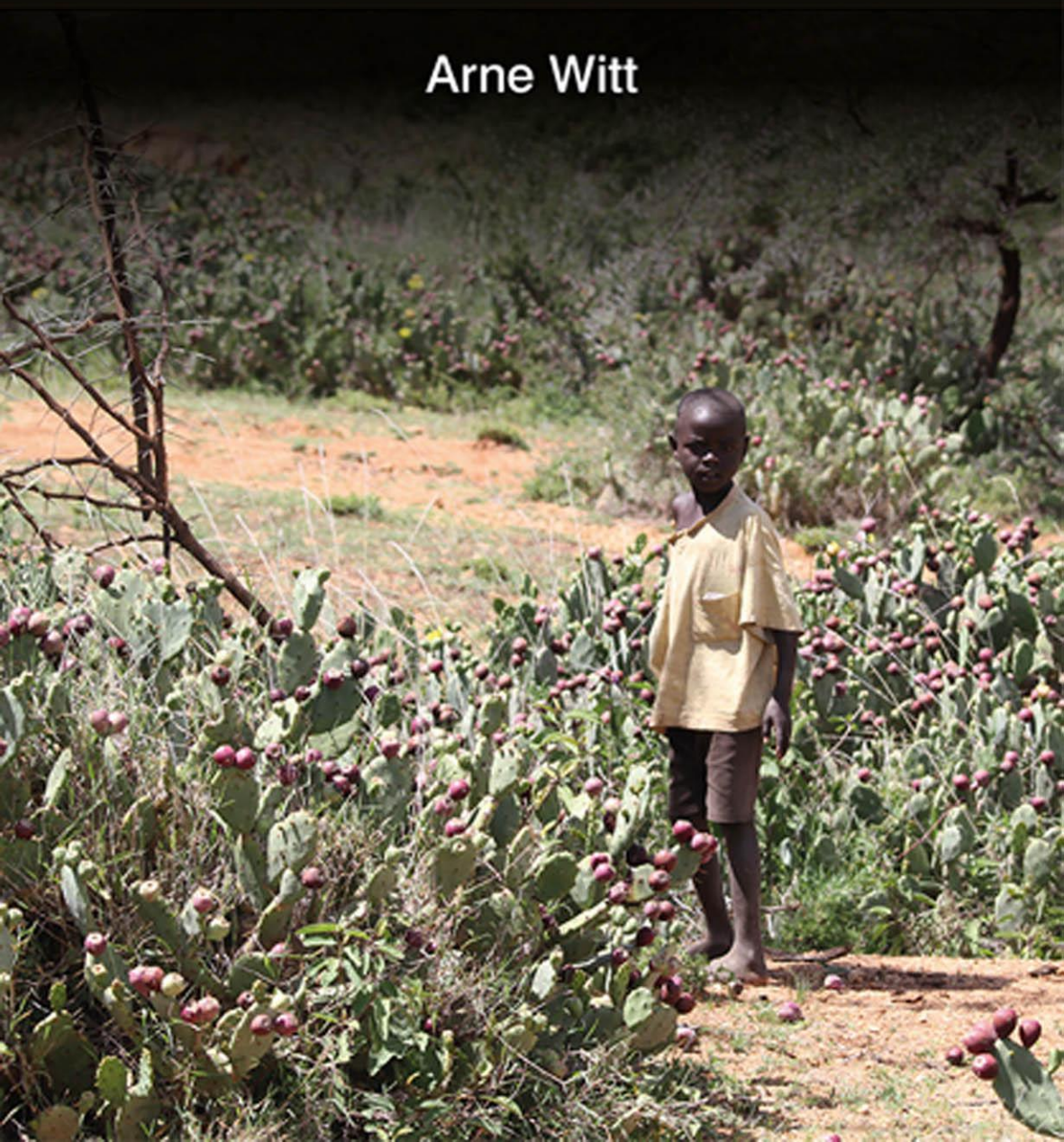
GUIDE TO THE NATURALIZED AND INVASIVE PLANTS OF

LAIKIPIA

Arne Witt



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Contents

Arne Witt is currently the Regional Coordinator for Invasive Species for CABI, based in Nairobi, Kenya. He has been involved in a host of IAS projects related to policy development, capacity building, awareness creation, and development and implementation of best management practices in Africa, Asia and the Caribbean. He continues to develop and implement IAS projects in these regions.

Arne has Master of Science degrees in Entomology and Conservation Biology and a PhD from the University of the Witwatersrand, South Africa. This is the third of a series of Field Guides he is authoring on invasive plants in Africa and Asia and follows on from his recently co-authored book *Invasive Alien Plants and their Management in Africa*.

Foreword

Established in 1966, UNDP works in some 170 countries and territories, helping to achieve the eradication of poverty, and the reduction of inequalities and exclusion. In 2016, 50 years later, UNDP is continuing its work to support the 2030 Agenda for Sustainable Development, and the 17 new Sustainable Development Goals (SDGs), or Global Goals, as they help shape global development for the next 15 years or more.

Under the Energy and Environment component of the Country Programme, UNDP supports Kenya to meet its obligations to international environment agreements, while enhancing the contribution of natural resources and the environment to poverty reduction and sustainable socio-economic development. However, the country's natural resource base is under considerable threat from a wide range of sources, including pollution, erosion, deforestation, encroachment, etc. One such threat of growing concern is the rapid spread of invasive alien species in several parts of the country.

Although there is insufficient information on the number of invasive plant species present in Kenya, their distribution, and the ecosystems under threat, we know enough about some of the worst species to be concerned, and that the problem will continue to grow, unless measures to halt their spread are taken. The GEF Small Grants Programme of UNDP, provided financial support to the Mpala Research Centre and CABI, to implement a project that would conduct an assessment of the presence of invasive plant species in Laikipia County, and thereafter produce distribution maps and an Identification Guide as a toolkit for use by affected communities, to create awareness on the troublesome plant species, and to provide methods of managing them.

UNDP, the implementing partner of the GEF Small Grants Programme, is pleased to support this project because it largely addresses the information-gap, and highlights the extent of the problem. The surveys conducted, and their subsequent analysis, provide important data that can be used by Laikipia County policy makers as well as other key stakeholders in devising strategies to manage invasive species effectively. Furthermore, local communities will have a better understanding of the spread and impacts of invasive plants, and be equipped to better manage them.

Country Director, UNDP Kenya

Foreword

Invasive alien species (IAS) pose one of the most worrying threats on earth to biodiversity, human livelihoods and sustainable development. As a result of increased global trade, travel and transportation, IAS can now be found the world over in virtually every habitat – from snow-capped mountains to forests, woodlands, savannahs, grasslands, deserts, wetlands, rivers, lakes, and marine environments. These plant and animal invasions have the biggest impact on poor rural communities, most of whom are directly dependent on the natural resource base for their immediate needs in terms of food, fodder for their livestock, water, medicinal plants, building materials, fuelwood and other products and services.

Kenya has not escaped this IAS onslaught, and neither has Laikipia County which stretches from the slopes of Mount Kenya in the southeast to the edge of the Great Rift Valley in the west, and which descends into the semi-arid and arid lands of northern Kenya. This area, known for its abundant wildlife and its pastoralist communities, is a mosaic of grasslands, savannah woodland and forest. All these habitats are threatened by a host of invasive alien plant species, such as Australian pest pear (*Opuntia stricta*) and other introduced cactus species, together with a number of alien herb, shrub and tree species. These non-native plant species are rapidly displacing indigenous plants and animals, and the forage on which thousands of cattle, goats and sheep depend. Strategies for the management of such foreign species can be developed and implemented only once the presence and distribution of these species is known and awareness created about their impacts.

As such, this Guide to naturalized and invasive plants in Laikipia is a timely and important contribution towards the future management of one of the biggest threats to biodiversity and livelihoods in the County and surrounding areas. The Guide includes detailed descriptions of these plants, together with line drawings and colour photographs, distribution maps and information on best management practices, making it a critical tool for managing invasive species in Laikipia. Indeed, the project that produced this Guide, funded by the Global Environment Facility (GEF) with UNDP as the implementing agency, has already contributed to the initiation of a biological control programme against Australian pest pear. We hope this will provide the impetus to support the control of other invasive plants in Laikipia County.

Arne Witt, the author of this Guide, and all those who have contributed are to be commended for their efforts in making information on the naturalized and invasive plants of Laikipia County available in a format that most people should be able to understand. This Guide will make a significant contribution to enhancing livelihoods and bolstering biodiversity conservation in Laikipia County.

Joshua Irungu, Governor, Laikipia County, Kenya

Foreword

Cradled between the Aberdare Mountains and Mount Kenya, Laikipia County is a land-use model for arid and semi-arid lands in Kenya. Its unique combination of large-scale ranches and community-owned lands host wildlife populations unrivalled in other parts of Kenya. Laikipia hosts the highest populations of endangered large mammals in Kenya, including half of the country's rhino population, together with significant populations of elephants, Grévy's zebra, reticulated giraffe and wild dogs.

More importantly, however, the generally intact nature of this landscape is the key to its success. Generally, residents tolerate and/or encourage the movement of wildlife across property lines. Conservation of wildlife and other natural resources is reflected in a land management ethic that places value on the nation's wildlife heritage. Landowners work hard to share the benefits accruing from this form of land use. Moreover, environmental services generated by this form of land use make Laikipia a potential economic hub for sustainable agriculture and wildlife conservation in the region.

Unfortunately, productive rangelands and livelihoods in Laikipia are threatened by the increasing prevalence of exotic plant species, many of which have already become invasive or have the potential to do so. Invasive alien plants displace native plants, especially valuable pasture species, to the detriment of wild animals and livestock which depend on the native plants.

For example, the invasive cactus, *Opuntia stricta*, which has already invaded thousands of hectares of private and pastoral lands, has contributed to a significant reduction in the amount of available forage, resulting in a negative impact on livestock health, forcing some people to abandon their homes in search of alternative lands. Many other cactus species, such as *Opuntia engelmannii* and *Austrocylindropuntia subalata*, are becoming just as problematic. Unfortunately, this list is growing. Without effective management, ever larger tracts of land will become unproductive.

This Identification Guide is the first step in raising awareness about the problem. With this Guide, we can now identify which naturalized and invasive species are already present in Laikipia; where they are growing, and whether they are abundant and/or widespread. The Guide also provides useful information on various management options. Of these options, prevention is paramount. We must actively engage in preventing the introduction into Laikipia of additional invasive plant species. And, in the case of those invasive species that are already present, we need to act decisively to stop their further spread. This Guide provides us with a valuable tool, which we can use to develop and implement county-wide rangeland management strategies.

Join me, then, in congratulating the author, Arne Witt, who has long held an interest in these 'alien' species in Laikipia, and let us thank him for giving us another tool in our sustainable rangelands management toolkit.

Peter E. Hetz, Executive Director, Laikipia Wildlife Forum, Kenya

Executive Summary

The impetus for the development of this Field Guide came about as a result of pleas from the community around the village of Doldol, Laikipia County, to initiate a control programme for Australian prickly pear [*Opuntia stricta* (Haw.) Haw.; Fabaceae], an invasive plant which was having a dramatic impact on livelihoods. However, a number of other exotic plants, which were less widespread, but had the potential of becoming invasive, were not seen as a potential problem. In order to avoid a similar situation from arising in the future, the community expressed a need for a Field Guide, which would include descriptions of naturalized and invasive species already present in, and those that were most likely to invade Laikipia County and, information on how best to manage them.

An additional impetus was to contribute to the four main objectives of the *National Strategy and Action Plan for the Management of Invasive Species in Kenya's Protected Areas*. The Field Guide contributes in some or other way to all of these objectives which are to (i) Enhance awareness of invasive species to relevant actors; (ii) Prevent new invasions, manage established invasions and rehabilitate degraded habitats; (iii) Enhance research, monitoring and information management on invasive species; and (iv) Enhance capacity, resource mobilization and coordination.

Extensive surveys revealed the presence of a number of introduced plant species which had escaped cultivation and established populations in the 'wild' to the detriment of natural resources and the people that depend on them. Introduced succulents, especially those in the genus *Opuntia* (Cactaceae), were found to be the most widespread and abundant invasive species in the semi-arid regions in the north and east of Laikipia County. Other succulents, those in the genus *Bryophyllum* (Crassulaceae), were also found to have escaped cultivation and were locally abundant. In the higher rainfall areas to the west and southwest, introduced trees such as black wattle (*Acacia mearnsii* De Wild.; Fabaceae) and Australian blackwood (*Acacia melanoxylon* R. Br.; Fabaceae) and the the shrubs/climbers, Mauritius thorn [*Caesalpinia decapetala* (Roth) Alston; Fabaceae] and yellow cestrum (*Cestrum aurantiacum* Lindl.; Solanaceae), were invasive. Introduced plants, which have the potential to become problematic in Laikipia, unless eradicated or controlled, have also been included in the Guide. This includes species such as famine weed (*Parthenium hysterophorus* L.; Asteraceae) and 'mathenge' [*Prosopis juliflora* (Sw.) DC.; Fabaceae], which are already abundant in areas adjoining the County.

Introduction

The main aim of this Identification Guide is to enable communities living within Laikipia County, Kenya (see Figure 1), and others in the region, to identify naturalized and invasive plant species and to inform them about the distribution and management of such species. All the plants described in this Guide are either present in Laikipia County or have the potential to become naturalized and/or invasive in the County – given that they are already widespread and abundant elsewhere within Kenya.

The book is sub-divided into six major sections: Aquatics, Climbers, Terrestrial Herbs, Small and Large Shrubs, Succulents and Small and Large Trees. Some species may be considered as both shrubs and small trees, or as both small and large trees, or as both shrubs and climbers, but have been included in only one of the sections or categories in order to avoid duplication. The species appear in alphabetical order within each section based on their scientific names.

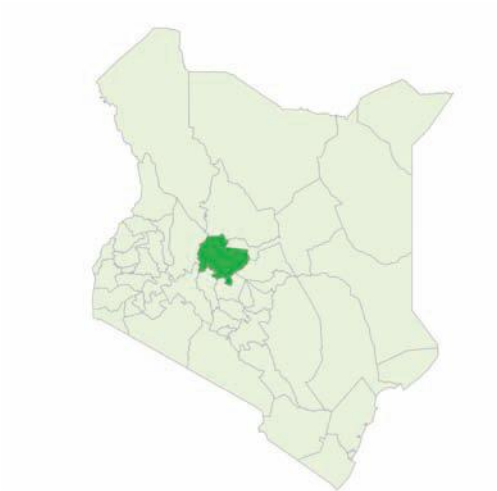


Figure 1. Map showing the location of Laikipia County in Kenya.

Where two or more species within the same genus are very similar in terms of their external morphology, only one species is fully illustrated, and differences are explained in the text. The text includes the scientific name for each species, together with its common English name and the local names that are most frequently used in Kenya. There is a brief description of the species, together with line drawings and colour photographs and information on their origin, reasons for introduction, habitats invaded and impacts. Information on impacts has been obtained from multiple sources, often from studies undertaken outside of Kenya. The data gleaned from such studies are considered to be generic, and at the very least the assumption can be made that the impacts of a particular invasive plant are similar, irrespective of where it is adventive.

The distribution maps are based on roadside surveys and surveys of towns, villages and gardens in Laikipia County, with the surveyed areas and distribution of naturalized and invasive species represented by 1/16 degree grid squares. In the species distribution maps grey grid squares represent the areas that were surveyed but where no naturalized, invasive or potentially invasive plant species were seen. Orange grid squares represent areas where the plant species was found to be naturalized, and red grid squares represent areas where the species was considered to be invasive. Yellow grid squares represent areas where the plant species was seen but was not considered to be naturalized or invasive.

The absence of any records within any surveyed grid square does not necessarily indicate that a naturalized or invasive plant species was not present within it; it just wasn't seen and as such recorded. In addition, due to poor road infrastructure and limited access, not all areas could be surveyed. However, the assumption is made that all widespread and abundant species present in Laikipia have been recorded, although some naturalized and (as of now) range-limited species may have been missed. The information on best management practices and on herbicide applications has been adapted mainly from sources in Australia and South Africa.

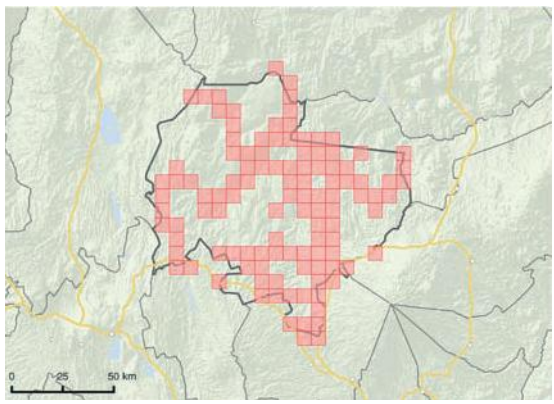


Figure 2. Map showing the areas surveyed in Laikipia County (surveyed area shown in 1/16 degree grid squares; ~11 x 11 km).

What is an alien plant?

An alien plant is an exotic, non-native, non-indigenous or foreign plant species that has been introduced by people, either intentionally or unintentionally, outside of its natural range and outside of its natural dispersal potential. Plants that have been introduced into an area without the help of people, from an area in which they are already exotic, are also regarded as alien. In other words, a species which does not belong to the native flora is alien. This includes most of our crops (wheat, maize, rice, potatoes, etc.) and many of our ornamental plants.

What is an invasive alien plant?

An invasive alien plant is a species of plant that is both alien, as described above, and destructive to the environment in which it grows. As such, invasive plants can have negative impacts on biodiversity and/or livelihoods. It should be noted that most alien species are useful and do not become invasive. In the context of this Guide, destructive alien species that were found to be widespread and abundant, or even localized but nevertheless abundant, were recorded as being invasive within a particular locality. The same criteria were used in recording the status of native species that we consider to be invasive.

What is a naturalized plant?

In the context of this Guide, a naturalized plant is an alien plant that has established self-perpetuating populations without any human intervention, but which is not yet considered to be invasive, in terms of being either widespread and/or abundant or destructive in the areas where it is found. Most plants that are considered to be naturalized go on to become invasive, but in many cases they do not. The same applies to those exotic species profiled in this Guide that are not naturalized or invasive in Laikipia County at present, but which have all of the characteristics or attributes of invasive species; some of these species may never become problematic, but we need to be conscious of their presence in the region.

What is a weed?

A weed is a plant that is out of place and which has not been sown intentionally, or it is a plant growing where it is not wanted. A weed has a negative impact on crop or pasture production, on human or animal health, or on other aspects of economic activity and development, and may be either native or introduced. Yet, while some native weeds may be problematic, in crop production systems for example, those very same species, often referred to as pioneers, may also play an important role in plant successions, say, in degraded forests. Pioneers, because they do not persist, allow natural succession to take place, unlike invasive alien species (IAS), which do persist and which inhibit or prevent natural succession processes. The definition of a weed is therefore context-dependent, but in the final analysis, while all invasive alien plant species are weeds, not all weeds are invasive alien plants, because many of them are native to the countries or regions where they occur.

Attributes that enable alien plants to become invasive:

- have no natural enemies in areas into which they have been introduced. In other words, there are no diseases or herbivores which have the ability to attack them, and so reduce their growth rate, reproductive capacity and competitive ability;
- are adaptable in that they are capable of growing in a wide range of habitats and soil types and under various climatic conditions;
- are often plants that have the ability to spread vegetatively (through cladodes, tubers, bulbs, etc.) as well as by seed;
- may be plants that are popular as ornamentals or which are used in agro-forestry, as these plants are more likely to be moved around and are grown in large numbers, contributing to increased propagule pressure;
- are often hardy, having the ability to withstand adverse growing conditions;
- have the ability to grow rapidly and to regenerate quickly after being damaged;
- establish easily, often in nutrient-poor or water-limited environments;
- can make very efficient use of limited resources such as water, nutrients and light;
- mature very rapidly and so produce seeds early, often in large quantities;
- possess efficient and effective modes of dispersal;
- do not require specialized pollinators, having flowers that are easily pollinated by any number of different insects, birds and other organisms, and
- have seeds that can remain dormant for long periods, allowing the plants to persist during periods which are not suitable for active growth.

Invasive alien plants may:

- interfere with crop and pasture production and native plants through competition for available light, water and nutrients;
- physically interfere with the growth of a crop or native plant species;
- displace crops, pasture and native plant species through the production of toxins that inhibit the growth of other plants (allelopathy);
- permanently alter natural ecosystems and the services and benefits they provide in nature and to people;
- impact on soil nutrient cycling (e.g. nitrogen-fixing plants);
- contaminate harvested crops with their seeds or by tainting (e.g. the seeds of some weeds are toxic, and may result in poisoning if consumed);
- act as secondary hosts for crop pests (i.e. harbour insects, pests or diseases which attack crops);
- provide suitable habitats for organisms that may pose a threat to human or animal health (e.g. waterweeds provide ideal habitats for vectors of human and animal diseases);
- increase shading (in the case of invasive shrubs or trees), which can alter soil temperatures, affecting the growth, reproduction and/or survival of organisms residing in the soil;

- have a negative impact on human and animal health (e.g. pollen from invasive plants may contribute to respiratory ailments in people);
- interfere with the harvesting of crops or forage (e.g. thorny or woody weeds can make it difficult to harvest crops);
- lead to the need for additional cleaning and processing (e.g. weeds with burs may lodge in sheep's wool);
- reduce the amount of available pasture (i.e. weeds may displace valuable pasture species or prevent access to valuable forage);
- be poisonous to people, livestock or wildlife;
- cause physical injuries to people, livestock or wildlife (e.g. weeds with spines, such as cactus species, can cause serious injuries);
- reduce the quality of animal products such as meat, milk, fleeces or hides (e.g. consumption of some weeds, such as parthenium, by livestock, may render their milk and meat unpalatable);
- invade water bodies, affecting water quality and quantity (e.g. waterweeds can dramatically increase water loss through evapotranspiration);
- inhibit water transport (e.g. waterweeds can inhibit or prevent the movement of boats);
- inhibit or prevent hydroelectricity generation (e.g. waterweeds may block turbines);
- block water courses, including irrigation canals (e.g. aquatic or semi-aquatic weeds), leading to flooding;
- inhibit the ability of people to catch fish (e.g. waterweeds, such as water hyacinth, which by covering entire water surfaces can make fishing impossible);
- alter river flows and contribute to riverbank erosion (e.g. semi-aquatic weeds, such as giant sensitive plant, which can reduce water flow rates);
- contribute to erosion of sand from beaches (i.e. weeds used to stabilize coastal dunes can alter soil movement dynamics, reducing sand deposition on beaches);
- interfere with the recreational use of certain areas, especially water bodies;
- reduce tourism potential (i.e. unpalatable weeds can reduce the abundance of wildlife);
- increase the frequency and intensity of fires (e.g. weeds, such as chromolaena, which are highly flammable);
- provide cover for dangerous animals and in many instances for poachers as well;
- prevent access to natural resources (i.e. weeds forming dense impenetrable thickets can prevent access to water and grazing);
- encroach on roads, paths and villages;
- contribute to the abandonment of homes and villages (i.e. a reduction in crop yields and pasture production may force people to move elsewhere);

- are drivers of human conflict (i.e. invasive plants, by eroding the natural resource base on which millions of people depend, may spark conflict, especially over access to water and grazing); and
- reduce visibility along transport corridors.

It has been estimated that weeds in general are causing crop-yield losses of about 10% in less developed countries, and of about 25% in least developed countries (Akobundu, 1987). In the USA, weeds are reducing potential crop yields by 12%, which equates to a monetary loss of about US$ 33 billion annually (USBC, 1998). Roughly US$ 27.9 billion of this lost crop-production revenue is attributed to exotic weeds (Pimentel *et al.*, 2001). In parts of the USA where infestations of field bindweed (*Convolvulus arvensis* L; Convolvulaceae) are dense, crop yields have been reduced by as much as 50–60% (Callihan *et al.*, 1990). Annual crops, such as cereals and grain legumes, are especially badly affected by bindweed infestations, and yield reductions of 20–80% have been recorded (Phillips and Timmons, 1954; Black *et al.*, 1994). Bindweed is also a problematic weed in vineyards. In 1998 alone, losses caused by bindweed in the USA were estimated at more than US$ 377 million (Berca, 2004).

In India, weeds are responsible for an estimated 30% loss in potential crop production, and are thought to be depriving the country of yields worth about US$ 90 billion per year (Singh, 1996). In India, yield losses of 86%, 67%, 48%, 27%, 25% and 18% have been recorded in niger seed, greengram, sesamum, soybean, black gram, pigeon pea and groundnut respectively, as a result of dodder (*Cuscuta campestris* Yunck.; Convolvulaceae) infestations (Mishra *et al.*, 2007). In the lowlands of Ethiopia, *Parthenium hysterophorus* L. (Asteraceae) is considered by the overwhelming majority of farmers to be the most damaging weed in both croplands and grazing areas (Tamado and Millberg, 2000).

Invasive plant species can also have a dramatic impact on livestock production. About 45% of the weeds in US pastures are alien species, which are together responsible for losses in pasture production worth about US$ 1 billion per year (Pimentel *et al.*, 2001). In Australia, infestations of rubbervine (*Cryptostegia grandiflora* Roxb. ex R. Br; Asclepiadaceae) have reduced the carrying capacities of some pastures by 100%. Economic losses incurred by rubbervine infestations, resulting in reduced cattle-carrying capacities and in increased management costs, have been estimated at A$ 18 million annually to the beef industry of north Queensland, Australia, alone (Agriculture and Resource Management, 2001).

In South Africa, infestations of *Chromolaena odorata* have reduced the carrying capacities of pastures from about six hectares per livestock unit (LSU) to more than 15 ha/LSU (Goodall and Morley, 1995). A recent study has shown that natural grazing capacity in South Africa, without management of invasive plants, would be reduced by 71% (van Wilgen *et al.*, 2008). In Australia, infestations of thistle [*Cirsium vulgare* (Savi) Ten.; Asteraceae] have caused losses to the wool industry amounting to an estimated US$ 15 million a year (Davidson, 1990). Most pasturelands in India have been invaded to some extent by *Lantana camara* L., (Verbenaceae), resulting in productivity losses worth almost US$ 1 billion per year (Pimentel *et al.*, 2001). It is estimated that

introduced weeds in crops and pastures in South Africa, the USA, the UK, India and Brazil result in economic losses of almost US$ 95 billion per annum (Pimentel *et al.*, 2001).

Invasive plants can also have a dramatic impact on water resources. In South Africa, invasive alien plants have reduced surface water run-off by about 3,300 million m^3, which is about 7% of the national total (Le Maitre *et al.*, 2000). Declines in water run-off in South Africa, attributed to infestations of *A. mearnsii* De Wild. (Fabaceae) alone, amount to an estimated 577 million m^3 annually (Versfeld *et al.*, 1998). Introduced pines (*Pinus* spp.) which have escaped from cultivation in South Africa have had a dramatic impact on water resources. On the Drakensberg in Kwazulu-Natal, pine plantations have reduced stream-flows by 82% (Bosch, 1979), while in the Western Cape stream-flows from invaded fynbos water catchments have declined by 55%. If the terrestrial invasive plants now present in South Africa were left to expand their distribution and to occupy their full potential ranges, water losses would increase to about 56% of the national total (van Wilgen *et al.*, 2008).

Infestations of water hyacinth [*Eichhornia crassipes* (Mart.) Solms; Pontederiaceae] and of other waterweeds can also dramatically increase water losses, impacting on a host of other sectors. In southern Benin, an infestation of water hyacinth was found to have reduced the annual income of 200,000 people by about US$ 84 million (de Groote *et al.*, 2003). Water hyacinth infestations are costing seven African countries US$ 20–50 million per year in impact and management costs (Joffe and Cook, 1997).

Invasive plants have negative impacts on human and animal health. For example, famine weed (*Parthenium hysterophorus*) can cause severe allergenic reactions in people who regularly come into contact with the plant (McFadyen, 1995). In Ethiopia, symptoms recorded in people who have come into contact with the weed on a regular basis include general illness, asthma, irritation of skin and pustules on the hands, stretching and cracking of the skin, and stomach pains (Wiesner *et al.*, 2007). Paper mulberry [*Broussonetia papyrifera* (L.) L'Hér. ex Vent.; Moraceae], a tree that is invasive in Ghana, Uganda, Pakistan and elsewhere, produces vast quantities of allergenic pollen, which has been shown to exacerbate asthma in sufferers. In Islamabad, Pakistan, paper mulberry sometimes accounts for as much as 75% of the total pollen count, contributing to ill health or even death in the old and infirm.

In Queensland, Australia, pastoral losses resulting from *L. camara* infestations were in 1985 estimated at US$ 7.7 million, inclusive of lost revenues associated with 1,500 animal deaths, and with reduced productivity and lost pasture production, as well as the costs of control (van Oosterhout, 2004). Invasive *Bryophyllum* species, including *B. delagoense* (Eckl. & Zeyh.) Schinz (Crassulaceae), caused 41 recorded poisoning incidents, affecting 379 cattle in Queensland, Australia, between 1960 and 1984 (McKenzie and Dunster, 1986). In 1997, 125 cattle died after eating this species on a travelling stock reserve near Moree in New South Wales, Australia (McKenzie *et al.*, 1987). In the Sudan, the ingestion by livestock of *Calotropis procera* (Aiton) Dryand.

(Apocynaceae) is a suspected cause of ill-health and sometimes even death in sheep and goats (Mahmoud *et al.*, 1979).

Biodiversity is also dramatically reduced by the presence of invasive plants. Indeed, many consider invasive alien species to pose the second biggest threat to biodiversity, after direct habitat destruction. In Australia, lantana alone is threatening the survival of 275 native plant species and 24 native animal species (Turner and Downey, 2010). On Ascension Island, *Nicotiana glauca* Graham (Solanaceae) is displacing endemic species such as *Euphorbia origanoides* L. (Euphorbiaceae), a critically endangered species, and *Anogramma ascensionis* (Hook.) Dielsby (Pteridaceae), through dominating sites and altering ecological conditions (Gray *et al.*, 2005). *Passiflora suberosa* L. (Passifloraceae) along with invasive plants of other species, is threatening *Platydesma cornuta* Hillebr. var. *decurrens* B.C. Stone (Rutaceae), a rare shrub that is endemic to Oahu, Hawaii, and of which only about 200 individual plants remain (Richardson, 2007). In Australia, herpetologists looking for reptiles in a habitat invaded by rubbervine (*C. grandiflora*) could find only a single lizard, compared with 131 lizards in nearby native vegetation (Valentine, 2006).

In South Africa, infestations of *Chromolaena odorata* (L.) R.M. King & H. Rob (Asteraceae) are having a negative impact on the breeding biology of the Nile crocodile (Leslie and Spotila, 2001), while in Cameroon chromolaena is displacing native species in the family Zingiberaceae, a major food source for the endangered western lowland gorilla (van der Hoeven and Prins, 2007). In Lochinvar National Park, Zambia, infestations of *Mimosa pigra* L. (Fabaceae) have reduced bird diversity by almost 50% and bird abundance by more than 95% (Shanungu, 2009). In South Africa, *Prosopis* spp. infestations have reduced bird species diversity in some guilds by more than 50% (Dean *et al.*, 2002). In Ethiopia, *P. juliflora* (Sw.) DC (Fabaceae) has reduced understorey basal cover for perennial grasses from 68% to 2% and the number of grass species from seven to two (Kebede and Coppock, 2015). Transformation of this habitat and the reduction in pasture species is threatening the survival of Grévy's zebra (*Equus grevyi* Oustalet; Equidae) in invaded areas (Kebede and Coppock, 2015).

Introduced plants that become invasive, unlike many other, perhaps more familiar invasive species, such as insect crop pests, generally have a cross-cutting impact, affecting multiple sectors, ranging from biodiversity to agriculture and pastoralism, and from water resources to human and animal health. Once an invasive plant has become established, and is widespread and abundant, it is virtually impossible to eradicate, with the result that its impacts on natural or human-made ecosystems will be permanent, unless ameliorated through ongoing, judicious management. This is why invasive alien plants pose such a menacing threat to livelihoods and economic progress, especially in the developing world, where most people are dependent on natural resources for their survival. It is therefore critical that we pool our efforts to manage this scourge, at the local, national, regional, and global levels.

Types of invasive plants

Invasive plants come in various growth forms, shapes and sizes. As mentioned in the Introduction, invasive plants in the context of this Field Guide have been grouped into Aquatics, Climbers, Herbs, Shrubs, Succulents, and Trees. While many of the invasive plants included in this Guide can be regarded as benign, others, if consumed by wildlife, livestock or people, are extremely toxic. The symbols used in this Guide provide users with a quick reference to the various growth forms – and to toxicity.

Toxic: These plants are poisonous and can have a negative impact on human or animal health and may even result in death, if consumed. Species which are toxic include famine weed (*Parthenium hysterophorus* L.; Asteraceae), lantana (*Lantana camara* L.; Verbenaceae) and common thorn apple (*Datura stramonium* L.; Solanaceae), among others.

Aquatics: Plants capable of growing in aquatic or semi-aquatic environments. These include species such as water hyacinth [*Eichhornia crassipes* (Mart.) Solms; Pontederiaceae] and water lettuce (*Pistia stratiotes* L.; Araceae). Some shrubs or small trees, such as giant sensitive plant (*Mimosa* pigra L.; Fabaceae), may also be regarded as semi-aquatic, although they have been included under the 'Tree' section in this Guide.

Climber/Vine/Creeper: Plants which can grow over and smother other vegetation. These include species such as Madeira vine [*Anredera cordifolia* (Ten.) Steenis; Basellaceae] and balloon vine (*Cardiospermum grandiflorum* Sw.; Sapindaceae). It should be noted that some large shrubs such as Mauritius thorn [*Caesalpinia decapetala* (Roth) Alston; Fabaceae], devil weed [*Chromolaena odorata* (L.) R.M. King & H. Rob] and even lantana (*Lantana camara* L.; Verbenaceae) may also be considered to be climbers as they have the ability to grow over other vegetation and 'climb' into trees. However, in this Guide the latter species are included under the 'Shrub' section, with the exception of Mauritius thorn, which is considered to be predominantly a climber.

Herbs: Small non-woody plants, usually no more than about 1 m tall, with generally green, soft, often single stems. These include species such as common thorn apple (*Datura stramonium* L.; Solanaceae); Mexican poppies (*Argemone* spp. L.; Papaveraceae); spear thistle [*Cirsium vulgare* (Savi) Ten.; Asteraceae], and famine weed (*Parthenium hysterophorus* L.; Asteraceae). Species such as *Catharanthus roseus* (L.) Don (Apocynaceae) and *Mirabilis jalapa* L. (Nyctaginaceae) are often considered to be herbs or shrubs, but in this Guide they are included under the 'Shrub' section.

Spreading or flat-growing herbs or ground covers: Plants with green, soft and horizontal stems that root wherever they come into contact with the ground. Examples include species such as Singapore daisy [*Sphagneticola trilobata* (L.) Pruski; Asteraceae] and creeping sensitive plant (*Mimosa pudica* L.; Fabaceae). The latter is sometimes also considered to be a small shrub.

Small shrubs: Woody plants that are smaller than large shrubs and trees, as described below. Often multi-stemmed and reaching heights of 1 m or less, these include species such as crofton weed [*Ageratina adenophora* (Spreng.) King & Rob.; Asteraceae] and Koster's curse [*Clidemia hirta* L. (Don.); Melastomataceae].

Large shrubs: Woody plants that are smaller than trees and often multi-stemmed, reaching heights of 2 m or more, and which can form dense stands. Examples include lantana (*Lantana camara* L.; Verbenaceae), devil weed [*Chromolaena odorata* (L.) R.M. King & H. Rob], and C*estrum aurantiacum* (Lindl.) (Solanaceae). Many of these large shrubs have the ability to climb over or into other vegetation, and so may also be regarded as climbers. However, in this Guide they are included under the 'Shrub' section.

Succulents: Plants with thick, fleshy leaves or stems, used for storing water. Usually found in arid or semi-arid regions, these include species in the genus *Opuntia*. Many of these species, such as sweet prickly pear [*Opuntia ficus-indica* (L.) Mill.; Cactaceae], may also be considered to be shrubs or even small trees. Some succulents, such as *Bryophyllum fedtschenkoi* (Raym.-Hamet & H. Perrier) Lauz.-March, may be considered to be ground-covers, herbs or even small shrubs, but in this Guide they are included under the 'Succulent' section.

Small trees: Woody plants that are larger than shrubs and which usually have only one erect perennial stem or trunk. Generally reaching heights of a few metres (less tall than 'large trees' as decribed below), these plants have wide crowns and in many cases form dense thickets. Examples include calliandra [C*alliandra houstoniana* (Mill.) Standl. var. *calothyrsus* (Meisn.) Barneby] and pigeon berry (*Duranta erecta* L.; Verbenaceae), although some may consider the latter to be a large shrub.

Large trees: Woody plants that are larger than shrubs and which usually have only one erect perennial stem or trunk, supporting a wide crown, but which (unlike small trees) may reach heights of several metres. Examples include black wattle (A*cacia mearnsii* De Wild; Fabaceae) and 'mathenge' [*Prosopis juliflora* (Sw.) DC; Fabaceae], although the latter is sometimes regarded as a large shrub.

What can we do to manage invasive alien plants?

In order to be effective, all invasive alien plant management strategies need to consider activities related to: (i) prevention; (ii) early detection and rapid response (EDRR); and (iii) control.

Prevention: As most of the invasive plants present in Laikipia County were intentionally introduced, the most effective way to prevent further introductions is to prevent their introduction in the first place. To that end it is important to evaluate the potential of an introduced plant to become invasive prior to introduction. This can largely be determined by undertaking a Risk Assessment (RA) which, amongst other factors, considers the biology of the species, characteristics of the environment to which it is being introduced and if it has been recorded as being invasive elsewhere. Undertaking RA on exotic species which are already present should also be encouraged, so that those plant species which show a high risk of becoming invasive in the future can be eradicated, if possible. It should be noted that climate change, increased disturbance and propagule pressure are all factors that may drive an exotic species, which may appear to be benign now, to become invasive in the future. Prevention is the most cost-effective activity within a holistic invasive species management strategy. As the saying goes 'an ounce of prevention is worth a pound of cure'.

Early detection and rapid response (EDRR): If authorities, competent bodies or even landowners have failed to prevent the introduction of an invasive or potentially invasive species, and it has established in the field, it is critical that it be detected early and eradicated, before it becomes widespread and abundant. To that end it is important that a surveillance strategy be developed and implemented. If an invasive or potentially invasive species is detected, but it is already abundant and widespread, a containment strategy needs to be implemented to prevent its further spread and action taken to mitigate its negative impacts.

Control: If surveillance did not result in the early detection of a potentially problematic plant, and eradication is no longer feasible because it is already widespread and abundant, it is essential to implement a control strategy. A control strategy could include the use of cultural, physical or chemical methods or a combination of some or all of these measures, followed by rehabilitation or restoration. However, before any control is implemented it may be wise to consider these points:

- If possible, undertake a socio-economic survey among communities and/or other target groups to determine the impacts of the invasive plant species on livelihoods or other economic sectors. If there is disagreement among the community as to the costs and benefits of the target species, it is recommended that a cost–benefit analysis (CBA) be undertaken. To acquire sufficient information to undertake a CBA it may be necessary to undertake additional field trials/surveys to support or refute the findings of the socio-economic assessment.

- It is critical that action be taken in order to garner support for control of the target species from government officials and local communities. This may take the form of meetings, workshops and/or the development and dissemination of awareness material.
- Inform all stakeholders as to the identity of the target species, its impacts and management options. A lack of support from communities will be a major barrier to the long-term success of any management activities.
- Demarcate and map the area targeted for control and calculate the costs associated with any control activities – these should include the costs of equipment, transport, labour, herbicides, nurseries to grow plants for restoration activities, etc. Note should be taken of the presence of other invasive plants which may invade the area once the target species has been removed. Costs associated with their control also need to be included.
- Develop baseline data on the density, distribution and impacts of the target species in order to measure the efficacy of control operations and benefits to local communities.
- Ensure that you have sufficient resources to undertake initial control, for follow-up activities and if required rehabilitation or restoration.
- If best management practices are not known, or there is resistance from the community to the implementation of particular control activities, it is suggested that demonstration trials or similar be established to reassure communities about the efficacy and safety of selected methodologies.
- The most cost-effective way of managing infestations is to initially contain the current infestation and then initiate control of the less dense or isolated populations first before moving on to the densest stands. In other words management strategies should work from 'outside-in', clearing less dense infestations on the periphery of larger and denser infestations first.
- If clearing invasive plants in mountain catchments or similar, it is recommended that invaded areas in higher lying areas be cleared first before moving on to lower lying areas because plant propagules (seeds or vegetative material) are more likely to move 'downhill'. This is especially relevant when controlling invasive plants that have invaded riparian zones because most propagules move downstream along with the water flow.
- Try to remove invasive plants before they flower and produce seeds. This is especially relevant and applicable to new infestations detected during surveillance activities.
- It is not advisable to transport plant parts, especially seeds, rhizomes, tubers, bulbs or other vegetative material (e.g. cactus cladodes) from areas where they have been removed for disposal elsewhere. This will most likely contribute to the further spread of the target species. Ideally, the plants that have been removed should be destroyed and left on site.

Example of control methods

Invasive plants can be controlled using physical (manual or mechanical), chemical or biological means (see below for more detail). Cultural control which is the use of fire, flooding or grazing to reduce the abundance of invasive plants can also be used in conjunction with other control methods. Cultural control in crop production systems which can include crop rotation, the use of catch crops, winter ploughing, and irrigation management, can also be helpful in controlling problem plants. Overgrazing often facilitates plant invasions by reducing native plant cover, allowing exotic plants to establish and spread – most invasive species thrive on disturbance. Overgrazing can lead to a reduction in fire frequency and intensity. An absence of fires can facilitate the establishment and proliferation of many invasive plants, especially succulents such as cacti, which are sensitive to fires. Livestock owners should therefore practise rotational grazing and apply the correct stocking rates.

A critical component of invasive species management, which is often not implemented, is that of rehabilitation or restoration. Rehabilitation involves activities which convert a cleared piece of land into land suitable for use in terms of habitation or cultivation. The objective of restoration, on the other hand, is to restore land cleared of invasive species to a situation where it matches, as close as possible, the original condition. The latter may involve activities to restore various ecological processes. Cleared areas are very prone to re-invasion, while restored areas are more resistant to invasive plant regeneration and invasion. Restored areas generally also require fewer follow-up activities to remove emerging seedlings and to clear novel plant invaders, and as such can result in significant long-term cost savings.

In areas where degradation is not severe, restoration can be achieved through accelerated natural regeneration (ANR), which relies largely on activities or actions that facilitate natural processes, such as seed germination of native species from the soil seed bank. Factors such as overgrazing and fire, which may harm the regeneration of native plants, can be limited through judicious management. Livestock may be excluded during the regeneration process, while weeding, along with the application of fertilizers and of mulching around regenerating native plants, coupled with direct seeding and steps that will attract seed dispersers, are encouraged (FORRU, 2006).

ANR can be facilitated by enrichment planting or framework forestry. Enrichment planting simply means planting more trees or shrubs of the existing native species, in order to boost their population densities, or else planting trees and shrubs of other native species, in order to enhance overall species richness. Framework forestry involves planting the minimum number of tree species required to reinstate the natural processes of forest regeneration and biodiversity recovery. Framework species include indigenous, non-domesticated forest trees which, on being planted in cleared areas 'rapidly re-establish forest structure and ecological functioning' (Elliott *et al.*, 2003). The principles for grassland or savannah restoration are similar.

The most cost-effective way of controlling invasive plants is by combining two or more of the methods mentioned above – as in, for example, manual control applied in conjunction with chemical and/or biological control. This is commonly known as integrated pest management (IPM) and should be implemented whenever possible in order to reduce costs and improve the efficacy of control across a landscape.

The benefits of weed or invasive alien plant management or control are significant, and are well understood in crop production systems. However, few studies have looked at the costs and benefits of an integrated management strategy across a range of sectors, with the possible exception of biological control, which in almost all cases has shown a positive return on investment. Those few studies that have looked at the benefits of an integrated approach to invasive plant management across a range of sectors, have also found it to be a wise investment:

- Brown and Daigneault (2014) found that an integrated approach to the control of the invasive tree *Spathodea campanulata* Beauv. (Bignoniaceae) in Fiji, derived monetized benefits of US$ 3.7 for each US$ 1 spent even without explicitly considering biodiversity, culture and other non-monetized benefits of control.
- Costs of aquatic weed control in Florida in the late 1960s were estimated to be US$ 6 million annually and benefits were reported as US$ 82 million, with the largest benefits coming from increased land use (due to drainage) and prevented flood damage (Lovell *et al.*, 2006).
- An analysis of the costs and benefits of the invasive Australian tree, *Acacia mearnsii,* in South Africa, suggest that a 'do nothing' scenario (with no attempts being made to control the spread of the species beyond the limits of plantations) is not sustainable, as the cost:benefit ratio is around 0.4 (de Wit *et al.*, 2001). The most attractive control option will be a combination of biological control of the whole plant (flowers, seed pods, leaves and stems) and physical clearing, assuming commercial growers can protect plantations at a low cost (cost:benefit ratio of 7.5) (de Wit *et al.*, 2001).
- Based on current values, if the invasive tree *Miconia calvescens* DC. (Melastomataceae) is allowed to expand and reach its full distribution in Hawaii, its impacts on forest ecosystems will amount to US$ 3.08 and US$ 4.6 billion on Oahu and Maui, respectively (Burnett *et al.*, 2007). To retain the current population into perpetuity will cost US$ 10.5 and US$ 73.5 million for Oahu and Maui, respectively. However, if Oahu switches to the optimal policy of population reduction, instead of spending US$ 321,000 per year from today into the future, a present value benefit of US$ 6.5 million can be realized. If Maui switches to an optimal policy of population reduction, a net present value benefit of US$ 34.5 million is possible (Burnett *et al.*, 2007).
- Under a dynamic simulation of an ecological-economic model of alien plant control, in a mountain fynbos ecosystem in South Africa, it was found that the cost of proactive clearing would range from 0.6% to 4.76% of the economic value of ecosystem services, but increases the value of these services between 138% and 149%, depending on the assumptions of the model (Higgins *et al.*, 1997).

- De Lange and van Wilgen (2010) estimated the value of ecosystem services in South Africa at ZAR 152 billion (presently, about US$ 19.7 billion) annually of which an estimated ZAR 6.5 billion was lost every year due to invasive alien plants. However, the loss would have been an estimated additional ZAR 41.7 billion had no invasive plant control been carried out. Between 5% and 75% of this protection was due to biological control.

Cultural control

Cultural control of invasive plants can include the use of grazing, flooding, and fire. Grazing can either promote or reduce weed abundance at a particular site. Increased disturbance as a result of the presence of livestock or other grazers can actually facilitate densification and the spread of some invasive plant species. However, if grazing treatments can be combined with other control techniques, such as herbicides or biocontrol, severe infestations can be reduced. Flooding can also be effective in controlling some invasive plant species, but is very difficult to implement in natural environments, and as such rarely used. Fire is more widely used to control unwanted plants in the natural environment and when combined with other control methodologies can be effective.

Fire can be a very cheap and effective way of controlling specific invasive plant species but its efficacy largely depends on the target species, the ecosystem in which it occurs, the intensity of the fire and the amount of times (frequency) it can be applied. For example, fires may actually stimulate seed germination of some plant species and as a result contribute to their densification, while species, which are usually susceptible to fires, may actually benefit from a controlled burn if it is implemented at the wrong time of the year. For susceptible species, the efficacy of a controlled burn can be further enhanced if used in combination with other control techniques, such as herbicides and biocontrol.

Fire: Especially effective for controlling succulents such as species in the Cactaceae and Crassulaceae. Can also be used to reduce the abundance of young seedlings or saplings of other invasive plants and can be used to control invasive grasses. Control efficacy is enhanced if used in combination with herbicides. For example, the significant biomass of clump grasses can be reduced using fire, and herbicide can then be applied to the emerging shoots, reducing the amount of herbicide that would normally have to be used in the absence of fire. However, before using fire it is critical to understand the ecology and phenology of the target species, when it is most susceptible to fire, and if there is sufficient combustible material in the system to carry an "effective" fire. Precautions should also be taken to prevent the fire from spreading to areas outside of the target area.

Physical control

Manual and mechanical: Manual control involves the direct removal of the above-ground parts of a plant with an axe or a slasher, or the uprooting of plants using a hoe, a garden fork or a spade, or by hand pulling. It may also include ring- and strip-barking. Mechanical control may involve the use of machinery or equipment (e.g. bulldozers or tractors and can, among others, involve pushing, stick-raking, blade ploughing and/or chaining of larger plants or medium density infestations). Mechanical control is often used to remove dense stands of woody weeds but can be expensive and may leave soils bare and so susceptible to erosion and re-invasion by invasive plants of the same species or of other species. Soil disturbance associated with manual control may stimulate the germination of weed seeds in the soil seed bank.

1. Uprooting: Physically removing a weed from the ground using tools such as hand-hoes, picks, garden forks, mattocks or even the "tree popper". Suitable for most weeds, especially when in the seedling stage. Not suitable for weeds with deep root systems or which produce suckers. All below-ground plant parts, which can result in the re-establishment of the target species, need to be removed and disposed of in a safe and effective manner.

2. Hand pulling: Similar to uprooting and widely used to remove seedlings and young plants of most invasive plant species; works best when the soil is moist. Take hold of the stem at ground level and pull out vertically. Try to remove plants when they are not fruiting in order to limit the spread of seeds. All below-ground parts of target species, which have rhizomes, tubers or other regenerating vegetative structures, need to be removed and disposed of to prevent their re-establishment.

3. Slashing or felling: A mower, slasher, machete, axe, saw or other tool is used to cut down a plant just above the soil surface. Only suitable for use against weeds that do not coppice or regrow from the rootstock (e.g. *Pinus* species). However, some species, such as *Acacia mearnsii*, will coppice readily from cut stems less than 10 cm in diameter, but larger trees will not do so. Felling can also be used in combination with foliar herbicide application for species that coppice or regrow. For example, large shrubs can be cut down at ground level and herbicide applied to the coppice or regrowth.

4. Ring barking: Removing a 30 cm band or strip around the stem or trunk of a shrub or tree at a height of about 50 cm. It is important to remove all of the bark and cambium. Not suitable for use on multi-stemmed plants, or on plants that coppice or produce root suckers. Hardwood species generally die after ringbarking, whereas most softwood species can survive ringbarking.

5. Strip barking: Stripping all of the bark from the stem or trunk from about 75 cm to below the soil surface using an axe or similar tool. Only suitable for species with bark that strips easily (e.g. Australian *Acacia* species).

6. Mechanical control: The use of heavy machinery, such as tractors or bulldozers, in conjunction with ploughs or similar equipment. For example, blade ploughing, grubbing and chaining is utilized in Australia to control invasive *Prosopis* species. Ploughing can also be used to control herbaceous plants, although this is largely limited to crop production systems. Aquatic weeds can also be removed mechanically from water bodies using 'harvesters'.

Advantages of manual control

- In most cases, little training or supervision is required.
- Tools are simple, cheap and easily obtainable in all countries – and with hand pulling no tools are required.
- In most cases, little or no harm is caused to the environment – desirable vegetation is not damaged by the hand pulling or uprooting of weeds.
- It can be used in countries where no herbicides are registered for use against a particular weed species.

Disadvantages of manual control

- Procedures are labour intensive, and can be expensive in countries with high labour costs.
- It is physically demanding and slow, and it usually requires repeated follow-up operations.
- Where machinery is used, manual control can be expensive – incurring fuel and maintenance costs.
- Soil disturbance may stimulate seed germination among weeds, and on steep slopes or on riverbanks this may also exacerbate soil erosion.
- In dense infestations, native species are often inadvertently damaged or removed.

Chemical control (adapted from Bromilow, 2001)
Chemical control is the use of herbicides, applied alone or in combination with other methods. A herbicide is a naturally occurring or man-made substance that alters the metabolic processes of a plant, so the plant is either killed or suppressed, or its growth habit altered. Herbicides can be divided into groups according to their modes of action. Non-selective herbicides will affect any plant they come into contact with, whereas selective herbicides can, for example, be used in crop production systems to kill weeds without impacting on the crop itself. However, it is important to recognize that non-selective herbicides can be applied selectively. For example, tree stumps can be treated with little risk to other plants growing nearby. Non-selective herbicides can also be injected into target species without affecting nearby plants.

Contact herbicides affect only the plant tissue they come into contact with, whereas systemic herbicides are translocated or moved throughout the plant from the initial point of application. So, for example, a chemical applied to the stem can be translocated to the roots and leaves, eventually killing the whole plant. Translocated herbicides may move either through the phloem (the living tissue which transports carbohydrates from the leaves or storage organs) or the xylem (non-living tissue that moves water and minerals from the roots to the shoots). Translocated herbicides can be selective or non-selective.

Pre-emergence herbicides, applied to the soil before weeds emerge, are often used in crop production systems, but are rarely used to control invasive plants in natural environments. Post-emergence herbicides, applied to weeds after they have emerged, are most frequently used to control environmental weeds.

It is important, in many cases, that herbicides are applied together with an adjuvant or adjuvants. Adjuvants are substances added to spray mixtures to enhance the efficacy of herbicide applications or application characteristics. They may include buffers and acidifiers, compatibility agents, de-foaming agents, deposition aids, dyes, stickers and surfactants. In some cases, the addition of an adjuvant is recommended, but in others it is important they are not used. Surfactants are the most important adjuvants because they facilitate the movement of the active ingredient into the plant. They include 'surface-active' chemicals such as penetrators, wetters, stickers and spreaders. These chemicals change the surface tension of the spray droplets, enhancing the spreading of droplets and their adherence to leaf surfaces.

- **Wetters** reduce the surface tension of spray droplets, facilitating their spread over the leaf surface. This also makes it easier for spray droplets to adhere to a waxy or hairy leaf surface. Many of these products are based on soaps or detergents.
- **Stickers** improve the retention of spray droplets on the plant once good wetting and coverage has been achieved.
- **Penetrants**, as the name implies, increase the penetration potential of the applied chemical into the plant.
- **Carriers** are used to dilute or suspend a herbicide formulation during its application – water and diesel are the most commonly used. Diesel can also assist in penetration.
- **Anti-foam agents** prevent the formation of foam in the spray tank, preventing the loss of active ingredients in the foam.
- **Anti-evaporants** are added to slow the evaporation of droplets of volatile herbicides, giving the herbicide more time to penetrate the target plant.
- **Emulsifiers** promote the suspension of one liquid in another, allowing the product to mix with water or oils such as diesel.
- **Solvents** are used in liquid formulations to disperse the active ingredient uniformly in the medium.
- **Stabilizers**, already present in most herbicide formulations, promote and maintain a uniform distribution of active ingredient throughout the spray

tank, while prolonging the shelf life of the active ingredient(s). Products are available which can be added to enhance the effect described.

- **Buffers** maintain the desired pH (acid or alkaline) of spray mixtures in the tank.
- **Drift control agents** control the size of spray droplets.
- **Dyes** are substances that stain areas where the herbicide has already been applied in order to show visually which plants have already been sprayed or treated and which have not.

A herbicide formulation will therefore include:

- the active ingredient(s);
- additives that enhance herbicide effectiveness, stability or ease of application, such as surfactants and adjuvants; and
- other additives such as solvents, carriers or dyes.

Factors that influence the efficacy of herbicides

- Seedlings are very sensitive to foliar applied herbicides – those of the contact type especially. On the other hand, systemic herbicides require both a large leaf area and active plant growth for efficient translocation.
- Stressed plants cannot absorb or translocate a herbicide efficiently.
- Rainfall or irrigation immediately after application can wash a chemical off the plant before it has been absorbed.
- Sometimes, if a mixture of products is used, one of the products may interfere with the action of another, reducing the overall efficacy of the application. Conversely, some chemicals can complement or enhance the efficacy of others.
- Insufficient coverage, resulting from the use of incorrect equipment, may reduce the efficacy of the application.
- Sediments, in the form of fine organic matter or clays in dirty water, may block spray nozzles. Active ingredients may bind with suspended solids and reduce their efficacy.

Advantages of chemical control

- In many cases, there are no other effective options.
- In most cases, chemical control is more cost-effective than other methods, especially manual control.
- Results are quicker than with manual control, especially when compared with ring-barking or stripping.
- Use of the correct herbicides, applied according to label recommendations, has little to no negative impacts on the environment.

Disadvantages of chemical control

- The purchase of specialized equipment and the training of applicators are essential, and can add to costs.

- Herbicides can be expensive – incorrect formulations can result in poor control, requiring repeated applications, which can add to costs.
- Target species must be 'healthy', and weather conditions suitable, at the time of a herbicide's application.
- Foliar application can affect non-target species.
- Herbicide misuse may cause environmental damage.
- Manual control of plants may be necessary before herbicide application (e.g. in cut-stump treatments) or in the spraying of re-growing or coppicing plants that were too tall to spray initially.

IMPORTANT NOTES

- Always read the product label and follow all instructions relating to safe and proper use of the product.
- Always wear protective/safety gear when applying herbicides.
- Only apply herbicides that are registered for use against a particular target species in your country.

1. Foliar applications:

Foliar spraying is the use of a herbicide, diluted with water, sprayed over the foliage (leaves and stems) of seedlings, shrubs, grasses or dense vine infestations to the 'point of runoff' (until every leaf is wet). Some herbicides will require the addition of stickers and wetters in order to improve efficacy. With plants that have been slashed or cut down, the coppice or regrowth should ideally have reached a height of 50–100 cm before spraying, if effective control is to be achieved. This method of control should generally be considered only for large and dense infestations where risks to non-target species are minimal. Efficacy may be influenced by: (i) the available surface area of the leaves; (ii) the position of the leaves; (iii) hair density on the leaves; and (iv) the thickness of the waxy layer on the leaves.

NB: Poor water quality may reduce a plant's herbicide uptake. Soil particles in water may also block spray nozzles. Active ingredients may bind with clay particles in the water, further reducing efficacy. As such, river water should not be used.

Advantages of foliar application

- Easy to apply.
- Large areas can be sprayed in a relatively short period of time.
- Small areas, or even individual plants, can be targeted.
- Ideal for follow-up work to kill seedlings or coppicing plants.
- Herbicides can be applied at lower concentrations than are needed for basal bark or cut-stump treatments.
- Minimal soil disturbance.
- Relatively cheap.
- Not labour intensive.

Disadvantages of foliar application

- Cost of spray equipment.
- Inconsistent or inadequate application rates, influenced by factors such as difficult terrain (steep slopes, rocky outcrops, etc.) and high plant densities, or by laxness on the part of operators.
- A herbicide's efficacy, as determined by its rate of uptake by targeted plants, may be affected by a host of environmental factors, as well as by the condition of the plants. For example, rainfall shortly after application will wash off the herbicide. Uptake will also be reduced in plants that are covered in dust, or which are stressed (through high temperatures, drought, water-logging or leaf damage caused by diseases or by insect attack).
- Can be undertaken only during the growing season of the plants.
- Cannot be applied in windy areas, while the wind is blowing.
- Potential spray drift may result in off-target damage.
- Large quantities of clean water are required at a spray site.

2. Stem applications:

No pre-treatment of the targeted plant is required. Herbicide is applied directly to the stem of the growing plant.

a. Basal stem application: Usually applied to thin-barked woody weeds, tree saplings, regrowth and multi-stemmed shrubs and trees with basal diameters of no more than 20 cm. The entire circumference of the trunk or stem from ground level to a height of 30–100 cm is sprayed or painted. To help bark penetration, an oil-soluble herbicide is mixed in diesel/kerosene/mineral turpentine/ penetrating oil/mineral oil or in other formulated oil blends. The full circumference of every stem or trunk rising from the ground needs to be saturated with the herbicide solution. Trees with old or rough bark may require increased coverage. Application may be made at any time. Bark should not be cut or removed before a basal stem application. Herbicide uptake will be reduced in plants with trunks that have been scorched by previous fires.

b. Total frill: Using a hand-axe, a panga or machete, make horizontal cuts into the sapwood tissue of the stems or trunks of trees, vines or woody weeds, and then insert herbicide into the cuts. Cuts are made at waist height around the circumference of the trunk. While still in the cut, the axe or tomahawk is leaned out to make a downward angled pocket, to which 1–4 ml of herbicide solution is IMMEDIATELY applied (within 15 seconds of making the cut), using a syringe or hand-held sprayer. A partial frill requires a few large cuts on all sides of the tree (5–10 cm apart), while a total frill requires a complete ring of level downward slanting cuts near the base of the stem. DO NOT ringbark the tree, as this will decrease herbicide uptake into the plant.

c. Stem injection: Also called drill-and-frill. Using a battery-powered drill or similar tool, make holes (at a 45° downward angle) in the stems or trunks of trees, cacti, vines or woody weeds, and IMMEDIATELY (within 15 seconds of drilling the hole) apply herbicide in the drill hole, using a squeeze bottle or plastic syringe. This technique targets the sapwood (cambium growth) layer just under the bark, which will transport the chemical throughout the plant. Do not drill too deeply or you will get into the heartwood, which will not take up the herbicide. Drill four holes for smaller plants, and a maximum of 12 holes for large plants. Stem injection relies on the active uptake and growth of the plant to move the chemical through its tissues, so plants that are already stressed may not be killed.

Similar to this is the **tree spearing** method whereby a specifically designed tree spear is thrust into the base of the tree at an angle of 30–40° from vertical. A herbicide solution is applied IMMEDIATELY to the holes/cuts, which are spaced approximately 5 cm apart.

Advantages of stem applications

- Most procedures are simple and require little preparation or training.
- The ability to kill large standing trees in locations where felling might damage native vegetation.
- Minimal disturbance is caused to surrounding vegetation, and no soil disturbance.
- It is less labour intensive than felling trees (using cut-stump applications).
- It is target specific, with little or no potential for herbicide drift (hence minimal non-target impacts).
- It is ideal for controlling weeds that can be difficult to kill using other methods.
- Can be applied at any time of the year.

Disadvantages of stem applications

- The need for some training, in the case of certain procedures.
- Diesel, used as a carrier, can be expensive, and is usually more toxic to people than the herbicide itself.
- Dense infestations may require large quantities of diesel, which may contaminate the soil and/or water.
- Large standing trees that have been treated, and which are dying, may fall suddenly or drop branches, and as such may be dangerous. They also pose an increased fire hazard.
- The woody biomass within large trees cannot be utilized to offset control costs.
- Frill and stem injection techniques can be slow.

3. Stump applications:

These include procedures that involve cutting down a plant at the base of the stem, and then immediately applying herbicide to the stump.

a. Cut stump: Sometimes also referred to as "cut and spray" or "lopping/pruning". Sever the plant completely at its base (no higher than 15 cm above the ground), preferably horizontally using a chainsaw, brush-cutter, machete or even secateurs or pruning loppers (tool selection will depend on ease of cut, as determined by the thickness of the stem/trunk), and IMMEDIATELY apply herbicide (with a paint brush, a squeeze bottle, a sponge-tipped bottle or a spray bottle). Application delays of more than 15 seconds for water-based herbicides and 1 minute for diesel-soluble herbicides, from cutting to chemical application, will give poor results. For trees with trunks of large circumference, the herbicide solution should be applied only around the edges of the stump, targeting only the cambium layer. Apply to the point of wetting, but not to the point of runoff. Treatments can be applied at any time of the year.

b. Total stump: Sever the plant completely at its base (no higher than 15 cm above the ground) using a chainsaw, axe, brush-cutter or machete. Once cut, the herbicide solution can be sprayed or painted on to the exposed cut surface and to the sides of the stump down to the root collar area, using a knapsack sprayer, a paint brush, a drench gun or a hand-held spray bottle. This method is generally used on trees with stems of small circumference. For vines with aerial tubers (e.g. *Anredera cordifolia*), both cut ends have to be treated with herbicide. Hold cut stems in a container of herbicide solution for 15 seconds after cutting, so that maximum translocation will occur.

Advantages of stump applications

- They are target specific, with negligible potential for herbicide drift (hence minimal non-target impacts).
- Tall foliage can be treated.
- They are relatively cost-effective in that only small amounts of herbicide are used.
- One application is usually enough to kill the target plant.
- Can be done in winter – outside of the growing season.
- There is no soil disturbance.

Disadvantages of stump applications

- Cutting down trees or shrubs is labour intensive.
- It can be time-consuming when dealing with large infestations.
- May require some training.

- Felling large trees can damage native vegetation.
- Sudden removal of the canopy can stimulate seed germination among weeds, and expose the soil to erosion.
- Diesel, often used as the carrier, can be expensive, and is more toxic to people than the herbicide itself.
- Some herbicides are long-acting and may be absorbed by non-target plant species growing nearby.

4. Scrape and paint:

Scrape a very thin layer of bark, using a sharp knife, from a 10–30 cm section of stem (taking care not to cut through the vine), and IMMEDIATELY apply the herbicide to the exposed green underlying soft tissue (before the plant can seal). Removing a small portion of the bark will allow the herbicide to penetrate into the plant's sapwood. For large shrubs and vines, several scrapes, placed approximately 7.5 cm apart, may be required.

Advantages of scrape and paint

- It is effective because herbicide is placed directly on to the target plant, with the result that non-target impacts are negligible.
- It is relatively cost-effective in that only small amounts of herbicide are used.
- One application is usually enough to kill the target plant.
- Gradual defoliation of a target plant will allow plants of native species growing nearby to recover over time, while also preventing sudden exposure of the soil to erosion.
- There is no soil disturbance.

Disadvantages of scrape and paint

- It may require some training.
- Large standing trees that have been treated, and which are dying, may fall suddenly or drop branches, and as such may be dangerous. They also pose an increased fire hazard.
- It is labour intensive.

NB: The herbicides and the modes of application recommended for controlling most (for some of the plants we could not find any relevant information pertaining to herbicide use) of the species included in this Field Guide are those that are used in Australia and/or South Africa (see **Appendices C and D**). The recommended herbicides may not be available or registered for use against the target species in your respective countries. If legislation in your country prohibits the use of these herbicides, or they have not been registered for use against a particular target species, it is illegal to use them, unless temporary authorization for experimental trials has been

granted by a competent authority. It should also be noted that the information contained in this book is a guideline only and that all herbicide-users read and strictly follow all label instructions when using a particular pesticide. The author of this Field Guide encourages those that choose to use herbicides to:

- purchase products that are registered and fit for purpose;
- obtain the correct advice from accredited advisers;
- ensure correct handling, transportation and storage of products;
- always use protective gear when applying herbicides;
- always read the product labels and follow all instructions relating to the safe and proper use of the product;
- always use the recommended product mixtures;
- always use the recommended equipment;
- take all necessary precautions to avoid non-target impacts; and
- dispose of all containers in a safe manner ensuring that they will not be used for other purposes subsequent to disposal or have a negative impact on the environment.

Biological control

The use of host-specific natural enemies (pathogens, mites and insects) to control invasive plants has been practised for many decades by a host of countries, especially the USA, Australia, South Africa, Canada and New Zealand. The main aims of biological control are to:

- suppress plant vigour;
- reduce seed production;
- slow plant growth; and
- reduce the density of the weed infestation.

Biological control agents include: (i) gall-forming insects; (ii) defoliators (e.g. leaf-feeding beetles); (iii) leafminers; (iv) sap-suckers such as insects and mites with piercing and sucking mouthparts; (v) flower-, bud- and seed-feeders; (vi) stem-borers; (vii) crown-feeders; (viii) root-feeders; and (ix) disease-causing microorganisms such as bacteria, viruses, fungi and nematodes. In some cases, only one introduced biocontrol agent has been needed for success in controlling an invasive plant infestation. In most cases, however, effective suppression of a target plant species has been achieved through the release of multiple biocontrol agents, which attack different parts of the plant.

Over a period of 150 years, until the end of 1996, more than 350 species of invertebrates and pathogens were deliberately released in 75 countries for the control of at least 133 weed species (Julien and Griffiths, 1998). It was estimated (Winston *et al.*, 2014) that by the end of 2012, there were 1555

separate and intentional releases of 469 species of weed biological control agents against 175 species of non-native target weeds (when related taxa of unidentified plant species, such as some *Opuntia* species, are counted as single target weeds). These so-called 'classical' biocontrol projects have been conducted in a total of 90 countries (Winston *et al.*, 2014). At a national level, biocontrol programmes have achieved success rates of 83%, 80%, 61%, 51% and 50%, respectively, in New Zealand (Fowler, 2000), Mauritius (Fowler *et al.*, 2000), South Africa (Zimmermann *et al.*, 2004), Australia (McFadyen, 2000) and Hawaii (Markin *et al.*, 1992).

The main benefits of biocontrol (Greathead, 1995)

- Agents establish self-perpetuating populations, often throughout the range of a target weed, including areas that are not accessible using chemical or mechanical control methods.
- The control of a target weed is permanent.
- There are no negative impacts on the environment.
- The cost of biocontrol programmes is low, relative to other approaches, and requires only a one-off investment.
- Benefits can be reaped by many stakeholders, irrespective of their financial status or of whether they contributed to the initial research process.

An analysis of some biocontrol research programmes in South Africa found that benefit:cost ratios ranged from 34:1 for *Lantana camara* to 4,331:1 for golden wattle, *Acacia pycnantha* Benth. (van Wilgen *et al.*, 2004). It is also estimated that biocontrol agents present in South Africa have reduced the financial costs of mechanical and chemical control by more than 19.8%, or ZAR 1.38 billion (Versfeld *et al.*, 1998). It is further estimated that biocontrol programmes, if fully implemented in the future, may reduce control costs by an additional 41.4%, or ZAR 2.89 billion (Versfeld *et al.*, 1998). These findings are supported by studies in Australia which have found that every dollar invested in the weed biocontrol effort yielded a return of A$ 23.10 (Page and Lacey, 2006). There, the benefit:cost ratio for agriculture alone (in terms of both cost savings on control and increased production) was 17.4. If current annual expenditures on biocontrol research continue into the future, it is expected that weed biocontrol projects in Australia may provide, on average, an annual net benefit of A$ 95.3 million, of which A$ 71.8 million is expected to flow into the agriculture sector (Page and Lacey, 2006).

In southern Benin, the reduction of water hyacinth as a result of biocontrol has been credited with an increase in income of US$ 30.5 million per year to a community of about 200,000 people (de Groote *et al.*, 2003). If one assumes that the benefits stay constant over the next 20 years, the accumulated present value would be US$ 260 million – a benefit:cost ratio of 124:1 (de Groote *et al.*, 2003).

The invasive plants which have been described in this Guide, and for which biological control agents are available, are listed in **Appendix B**. All of the agents listed have established in the identified countries as indicated, although a number have proved largely ineffective, owing to a range of factors.

Summary guidelines for managing Invasive Alien Plants

When developing and implementing an invasive alien plant management strategy it is recommended that the following steps be followed:

- Inspect the area/property which has been identified for management;
- Record/map the location of all target species in the designated area, the habitats in which they are growing, and the possible presence of biological control agents;
- Identify all available control options and determine associated costs and benefits, including those for follow-up operations, being aware of the fact that physical and chemical control operations may have a negative impact on any biological control agents that may be present;
- Ensure that sufficient resources are available to reduce and maintain infestations to levels which have been pre-determined and agreed upon by all stakeholders;
- Undertake Environmental Impact Assessment's for management options, if required;
- Design, document and implement the management strategy based on inputs from all interested and affected parties;
- Regularly monitor effectiveness, including costs, of the control strategy;
- Record and share the results of the strategy in order to evaluate success and provide lessons learnt;
- Design, document and implement a long-term programme to prevent re-establishment or re-invasion of the cleared area. Ideally this should also include restoration.

Acknowledgements

This project would not have been possible without the contributions of many individuals and organizations over a period of 18 months. There is not space enough, here, to acknowledge the contributions made by each and every individual or organization, but you can rest assured that we are deeply grateful to everyone who has contributed in whatever way.

The idea of a Field Guide was born after repeated visits to Laikipia County to consider options for the control of *Opuntia stricta*. This species, already widespread and abundant, was having a damaging impact on native plants, wildlife, livestock and pastoralist communities. It became apparent, however, that a number of other exotic species had escaped cultivation, and that in time some of these species would pose just as big a threat as *O. stricta*.

In order to 'expose' these invasive plant species and to encourage their control or even eradication before they can became a serious menace, it was deemed necessary to create some awareness, and hence it was decided to produce an Identification Guide. Discussions with Margaret Kinnaird, the past Director of (MRC), resulted in the submission of a joint proposal to Nancy Chege, the National Coordinator of the Global Environment Facility (GEF) Small Grants Programme (SGP) in Kenya, who approved our proposal – for which we are extremely grateful. Ultimately this Project would have been possible without the financial support of the GEF through the SGP.

Surveys in Laikipia would not have been possible without the support and approval of landowners and pastoralist communities, and for this too I am extremely grateful. Accommodation was always provided on request by a number of conservancies. In this regard, I would especially like to acknowledge the assistance of John Weller, the General Manager of Ol Jogi Ranch, who has never declined a request for accommodation, and who has always provided assistance in all aspects. Francis Merinyi from Doldol, who was instrumental in highlighting the plight of his community as a result of the cactus invasions, and who was also the first person to invite me to Laikipia, facilitating all interactions with the local communities. Laikipia Wildlife Forum (LWF) was also supportive of our activities.

I am extremely grateful to colleagues Winnie Nunda and Julius Olumeh for their assistance with conducting surveys, entering data and sourcing relevant information. Thanks also to Rudolf and Imelda, who also assisted with the surveys, for their patience and support while I was putting this Guide together; and to Morris Akiri, CABI Regional Director, and Dennis Rangi, CABI Director General for International Development, for their support in this initiative. I am especially grateful to Sarah Hilliar (CABI) for her unwavering support and guidance with regard to the layout of the Field Guide and Tim Beale (CABI) for putting all of the distribution maps together. Joe Vitelli from Biosecurity Queensland, Department of Agriculture and Fisheries, Australia, kindly provided information on herbicide use, while Rachel Winston provided additional information for incorporation in the biological control table.

A number of references and source materials were used to glean information on various species and their impacts and management. I have unashamedly used a format similar to that used by the Kwazulu-Natal Branch of the Wildlife and Environment Society of South Africa in their Guide entitled *Invasive Alien Plants in Kwazulu-Natal – Management and Control*, as this was deemed to be the most popular format among potential users. The following additional sources of information were widely used and I would like to acknowledge all of them:

- The *Field Guide Alien Weeds and Invasive Plants* (2001) by Lesley Henderson was used to acquire additional information on the identification of some invasive plants.
- Guide to *Problem Plants of South Africa* (2001) by Clive Bromilow was largely used to glean information on herbicide use.
- Another Guide, *Naturalised and invasive succulents of southern Africa* by Walters *et al*. (2011) was useful in terms of the descriptions of succulent species.
- Sheldon Navie and Steve Adkins allowed me to use much of the information contained in the website *Environmental Weeds of Australia* (**http://keyserver.lucidcentral.org/weeds/data/media/Html/index.htm#A**).
- Information on the descriptions of some agroforestry species, known to invasive, was obtained from the World Agroforestry Centre website (**www.agroforestry.org**).
- Additional information of invasive plants was gleaned from the Global Invasive Species Database website (**http://www.iucngisd.org/gisd/**).
- Information of invasive plant impacts in the Pacific was largely obtained for the Pacific Island Ecosystem at Risk (PIER) website (**www.hear.org/pier/**).
- Comprehensive information on the origin, descriptions and impacts of invasive plants was obtained from CABI's Invasive Species Compendium (**www.cabi.org/isc/**).

Other source material used has been listed in the references.

Key to distribution maps

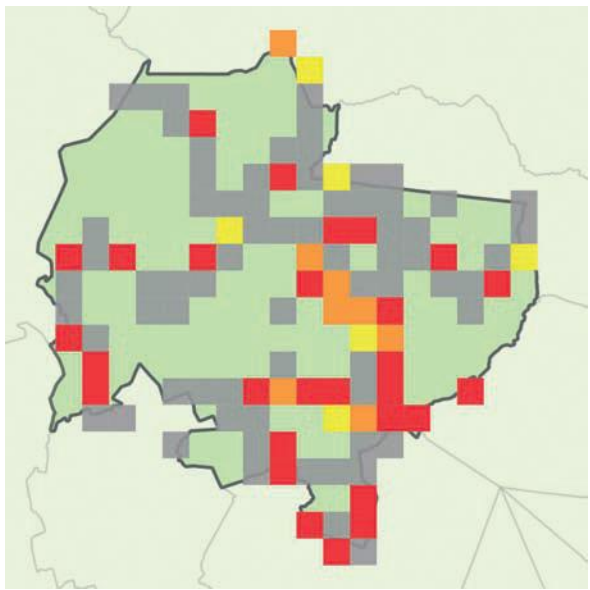
Surveyed areas and the distribution of naturalized and invasive species are represented by 1/16-degree grid squares (~ 11 x 11 km).

Areas that were surveyed but where no naturalized, invasive or potentially invasive plant species were seen.

Yellow grid squares represent areas where a species was present but not naturalized or invasive.

Orange grid squares represent areas where a species was found to be present and naturalized.

Red grid squares represent areas where a species was considered to be present and invasive.



Sample map

AQUATICS PAGE 35

Aquatic plants are plants that have adapted to living in aquatic (Water) environments, e.g. *Eichhornia crassipes* (water hyacinth).

CLIMBERS PAGE 45

A weak-stemmed plant that derives its support from climbing, twining, or creeping along a surface, e.g. *Caesalpinia decapetala* (Mauritius thorn)

HERBS PAGE 49

Any seed-bearing plant which does not have a woody stem, e.g. *Cirsium vulgare* (Scotch thistle).

SHRUBS PAGE 65

A woody plant which is smaller than a tree and has several main stems arising at or near the ground, e.g. *Lantana camara* (lantana).

SUCCULENTS PAGE 83

Plants having some parts that are more than normally thickened and fleshy, usually to retain water in arid climates or soil conditions, e.g. *Opuntia stricta* (Australian pest pear).

TREES PAGE 125

A woody plant, typically having a single stem or trunk growing to a considerable height and bearing branches at some distance from the ground, e.g. *Prosopis juliflora* (mesquite).

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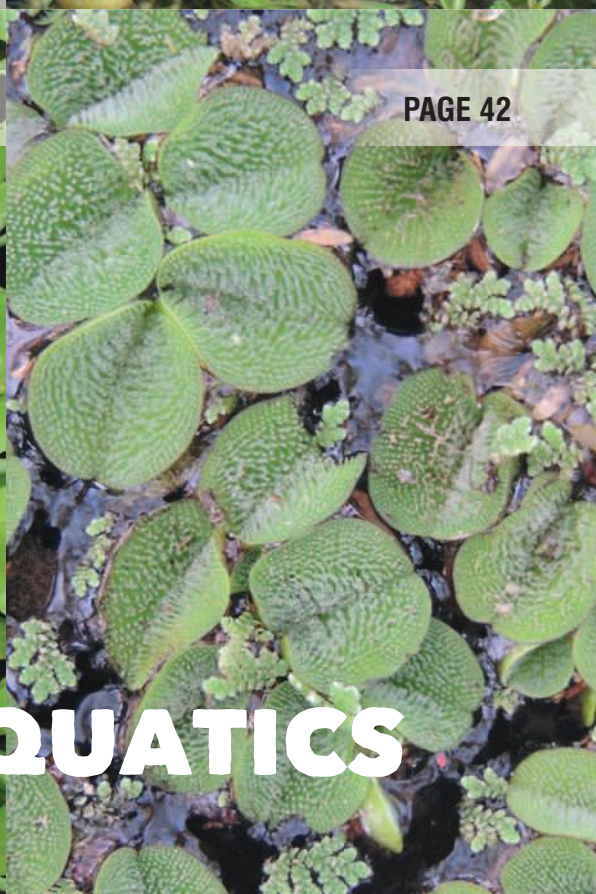

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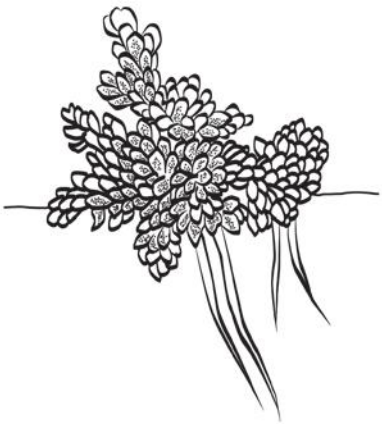
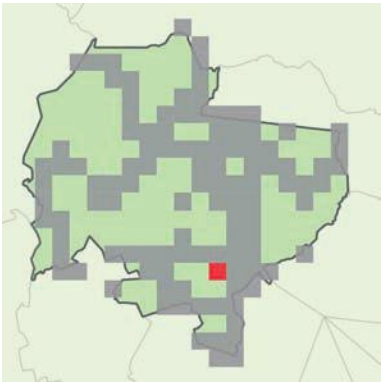
AQUATICS

Azolla filiculoides





MOSQUITO FERN FAMILY
Azollaceae

COMMON NAMES

English: azolla, large mosquito fern, red azolla, red water fern.

DESCRIPTION
Evergreen, free-floating, aquatic fern with horizontal stems (to 25–35 mm long); branching pattern is loosely alternate, the roots hang into the water and have fine laterals.

Leaves: Silvery-green turning reddish-brown or purplish in winter, broadly egg-shaped to almost circular (1–1.5 mm long), alternate and overlapping.

Fruiting bodies: Minute, in the axils of the leaves; reproduction also by detached plant fragments.

ORIGIN
Argentina, Brazil, Uruguay and Peru.

REASON FOR INTRODUCTION
Green manure, aquaria and ornament.

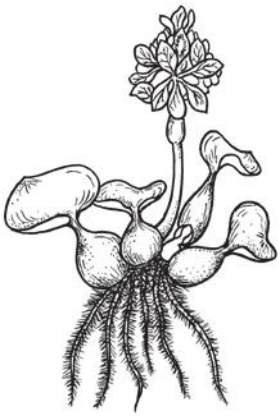
INVADES
Ponds, dams, floodplains, swamps, wetlands, lakes and slow-moving rivers.

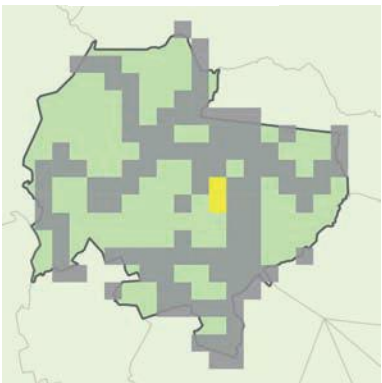
IMPACTS
Can grow in water that is low in nitrogen content. Mats, sometimes 30 cm thick, reduce water quality, impoverish biodiversity and increase siltation. Below the mats, which prevent light from penetrating, decaying root and leaf matter creates anaerobic conditions that are detrimental to aquatic organisms. The endangered fish species, the Eastern Cape rocky (*Sandelia bainsii* Castelnau; Anabantidae) is faced with extinction as the result of *A. filiculoides* infestations. Such infestations may also render water unpalatable to people, livestock and wildlife (Hill, 1997). Thick mats, mistaken for solid ground, result in the drowning of animals. Infestations increase water loss through evapotranspiration, while also providing habitats for vectors of disease. Impact costs in South Africa run to an estimated US$ 589 per hectare per year (McConnachie *et al*., 2003).

Recent evidence from South Africa indicates that *A. filiculoides* is predominantly invasive in colder areas, while *A. cristata* Kaulf. dominates in more tropical regions (L. Henderson, *pers. comm*.) *A. cristata* has prominent root caps while *A. filiculoides* often has curled root tips and less conspicuous root caps (L. Henderson, *pers. comm*.). Additional research is required to confirm if *A. cristata* is also present in eastern Africa, or if *A. filiculoides* has been incorrectly identified.

Azolla filiculoides Lam.

Eichhornia crassipes





PICKEREL WEED FAMILY
Pontederiaceae

COMMON NAMES

English: lilac devil, Nile lily, pickerelweed, water hyacinth, water orchid

DESCRIPTION
Evergreen, free-floating, aquatic plant that may become anchored in shallow water; [10–20 (–100) cm high]; roots are long and feathery; runners (10 cm long) are produced across the water surface and give rise to new plants.

Leaves: Dark green, shiny, hairless, simple, oval to egg-shaped to almost rounded (2–25 cm long and 2–15 cm wide) with swollen bladder-like stems (30 cm long).

Flowers: Pale violet or blue (4–6 cm long and 3.5–5 cm wide), upper petal of each flower has a prominent yellow-centred patch; flowers in clusters of 8–10.

Fruits: Capsules (a dry fruit that opens at maturity) (10–15 mm long), containing very fine seeds.

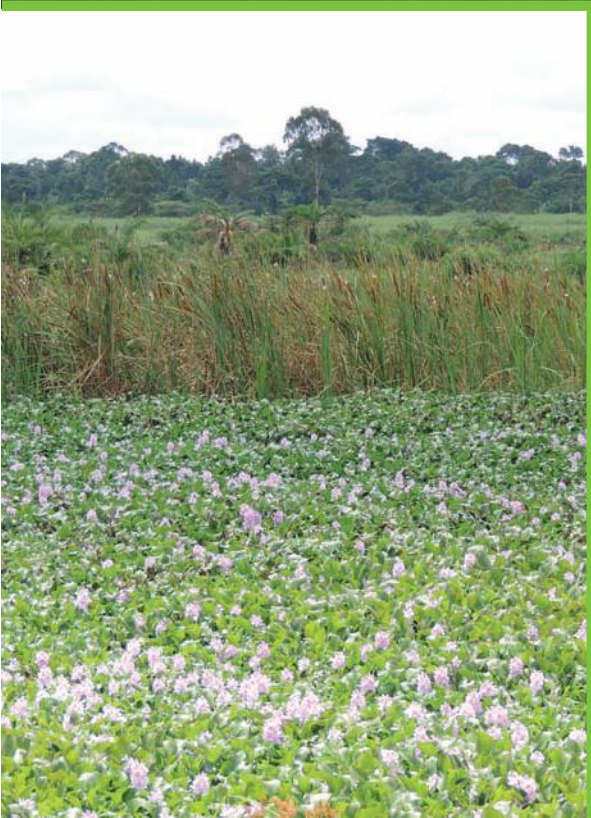
ORIGIN
Brazil, French Guiana, Guyana, Suriname and Venezuela.

REASON FOR INTRODUCTION
Ornament.

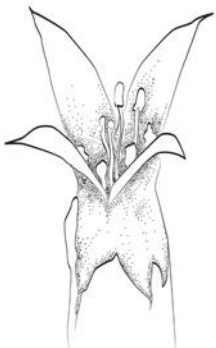
INVADES
Irrigation channels, dams, ponds, floodplains, swamps, wetlands, lakes and slow-moving rivers.

IMPACTS
This aquatic weed has the ability to form thick mats which hamper water transport; inhibit or even prevent fishing-related activities; block waterways and canals; hamper hydroelectricity generation; and provide breeding sites for vectors of human and animal diseases, increasing the incidence of malaria, encephalitis, schistosomiasis, filariasis, river blindness and possibly cholera (Burton, 1960; Spira *et al*., 1981; Gopal, 1987; Viswam *et al*., 1989). The thick mats reduce light penetration into the water, causing declines in the concentrations of phytoplankton that support the zooplankton–fish food chain. Extensive mats of water hyacinth increase water loss through evapotranspiration, and impact rice production (Waterhouse, 1993). In southern Benin, an infestation of water hyacinth reduced the annual income of 200,000 people by about US$ 84 million (de Groote *et al*., 2003). Lost revenues for men were mostly fishing-related, while women experienced lost revenues in trade, primarily of food crops and fish.

Eichhornia crassipes (Mart.) Solms



Pistia stratiotes



ARUM FAMILY
Araceae

COMMON NAMES

English: Nile cabbage, tropical duckweed, water cabbage, water lettuce

DESCRIPTION
Evergreen, mat-forming, usually free-floating aquatic plant; consists of a rosette of leaves (30 cm across) with a tuft of long, feathery roots (to 80 cm long); plants develop runners (to 60 cm long); resemble floating lettuces.

Leaves: Pale yellow-green or greyish-green, spongy, narrow at the base and rounded at the tips (2.5–15 cm long and 2–8 cm wide), margins with a series of curved projections, leaves ribbed with 6–15 longitudinal veins radiating from the base; soft white velvety hairs, which repel water, are found on the top and bottom of the leaf.

Flowers: Inconspicuous, pale green or white, arising from leaf forks.

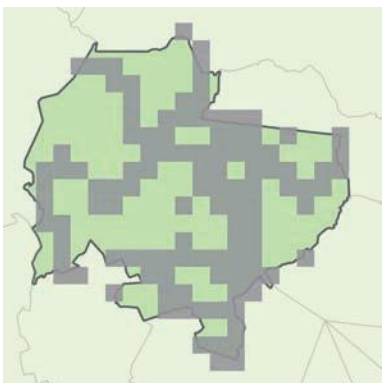
Fruits: Capsules (dry fruits that open at maturity), small, green, egg-shaped or oval, (5–10 mm long).

ORIGIN
Considered by some to be native to Africa, with a very ancient origin (possibly in the Tethus region), while others maintain that it is native to Brazil.

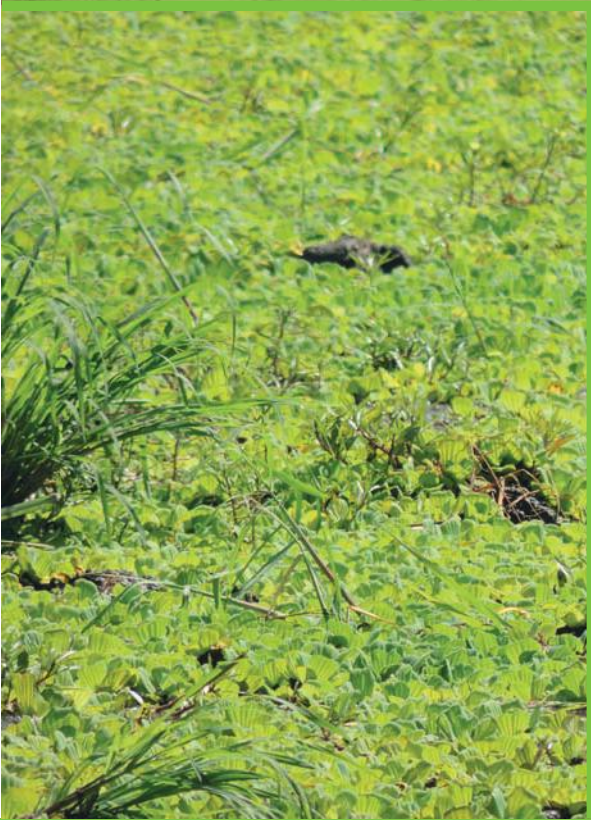
REASON FOR INTRODUCTION
Ornament.

INVADES
Irrigation channels, dams, ponds, floodplains, swamps, wetlands, lakes and slow-moving rivers.

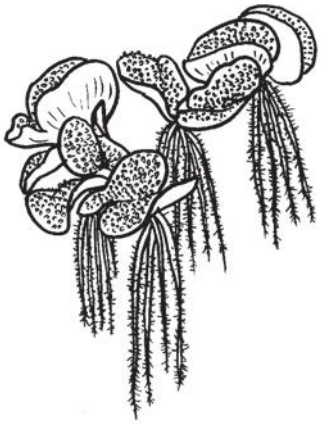
IMPACTS
Water lettuce infestations contribute to increased rates of siltation, slowing of water flow rates, degradation of fish nesting sites, increased nutrient loading, thermal stratification, increased alkalinity and fish and macro-invertebrate mortality (Dray and Center, 2002). Mats of water lettuce block waterways, making navigation difficult. Mats of the weed also hamper fishing activities, interfere with hydroelectricity generation and hinder flood control efforts. They provide habitats for vectors of disease, and can interfere with rice production (Holm *et al*., 1977; Waterhouse, 1993). Not seen in Laikipia County.

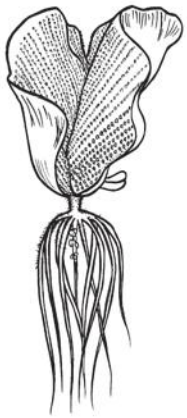


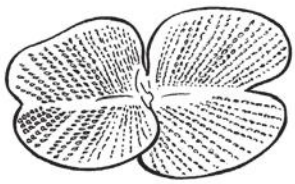
Pistia stratiotes L.

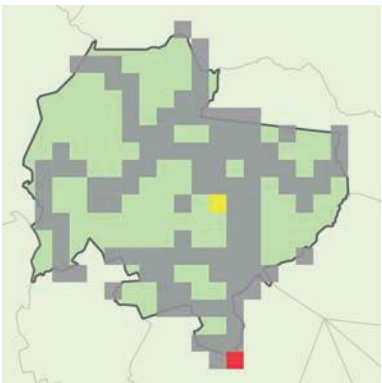


Salvinia molesta









WATERMOSS FAMILY
Salviniaceae

COMMON NAMES

English: aquarium water-moss, Australian azolla, butterfly fern, giant salvinia, kariba-weed, salvinia, velvet weed

DESCRIPTION
Evergreen, mat-forming, free-floating fern, branching horizontal stems (6–25 cm long and 1.2 cm thick), submerged feathery roots.

'Leaves': Green or yellowish-green fronds, in pairs, oval (2–6 cm long and 10–15 mm wide); almost impossible to wet due to a covering of fine egg-beater-shaped hairs (1–3 mm long) on upper surface; undersides covered in matted brown hairs.

Flowers: None

Fruits: None, reproduces from detached fragments.

ORIGIN
Brazil

REASON FOR INTRODUCTION
Ornament.

INVADES
Drainage ditches, irrigation channels, dams, ponds, swamps, wetlands, lakes and slow-moving rivers.

IMPACTS
Thick mats reduce light penetration into water bodies, impacting negatively on submerged aquatic plants. Infestations also often out-compete rooted and submerged native plants and in so doing, reduce plant diversity (Sculthorpe, 1985). Benthic fauna is usually also reduced (Coates, 1982), while fish can also be impacted by changes in oxygen concentrations as S. molesta plants die and rot within water bodies (Sculthorpe, 1985). It is also a pest of rice paddies in India, where it competes for water, nutrients and space, resulting in poor crop production (Anonymous, 1987). Dense mats also provide habitats for many human disease vectors such as *Mansonia* spp. mosquitoes, which have been identified as vectors of West Nile virus, St. Louis encephalitis, Venezuelan equine encephalitis and rural elephantiasis (Pancho and Soerjani, 1978; Chow *et al*., 1955; Ramachandran, 1960; Lounibos *et al*., 1990). Mats also harbour snails that transmit schistosomiasis (Holm *et al*., 1977). Infestations also impact negatively on water transport and fishing. For example, entire villages, dependent on water transport were abandoned along the Sepik River in Papua New Guinea when infestations of *S. molesta* limited access to healthcare, education and food (Gewertz, 1983).

Salvinia molesta D.S. Mitch

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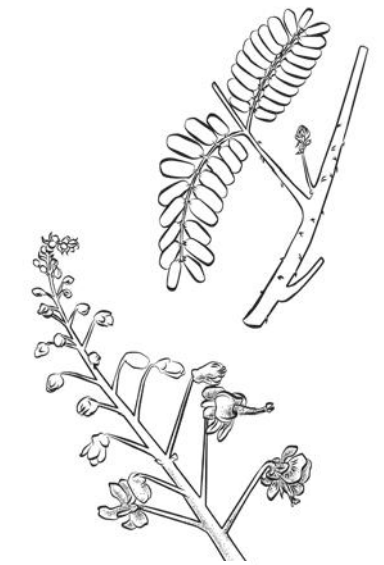
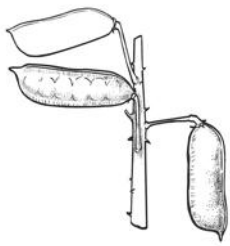
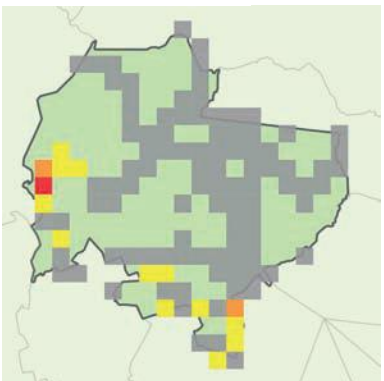
CLIMBERS

Caesalpinia decapetala







PEA FAMILY
Fabaceae; subfamily: Caesalpiniaceae

COMMON NAMES

English: cat's claw, Mauritius thorn, mysore thorn, shoofly, wait-a-while
Luhya: lunani, luavari, olunani
Luo: okwato, matata
Swahili: mkomwe
Kikuyu: mubage
Kamba: kitandambo
Kisii: ekenangwa
Maasai: oiti orok
Kipisigis: chepkomon

DESCRIPTION
Robust, thorny, evergreen shrub or climber [2–4 (–10) m high]; often forms dense thickets; stems have very fine golden hairs and numerous straight to hooked thorns, not in regular rows or confined to nodes.

Leaves: Dark green above, paler below, twice-divided (to 30 cm long); 4–10 pairs of leaflet branchlets with each branchlet having 8–12 pairs of leaflets which are egg-shaped or somewhat elongated with almost parallel sides, rounded at the ends (7–20 mm long and 2–8 mm wide).

Flowers: Pale yellow (25–30 mm wide), in elongated, erect clusters or spikes (10–40 cm long).

Fruits: Pods (several seeded fruits that split open at maturity), green turning brown as they mature, flattened (6–10 cm long and 25 mm wide), unsegmented and smooth with a sharp beak at the far or distal end; held stiffly erect on woody stalks.

ORIGIN
India, Bhutan, Sri Lanka, Laos Myanmar, Indonesia, Philippines, Thailand, Vietnam, Malaysia, China, Korea and Japan.

REASON FOR INTRODUCTION
Bee forage, hedge/barrier and ornament.

INVADES
Roadsides, disturbed land, wasteland, gardens, plantations, drainage ditches, forest, forest edges/gaps, woodlands, woodland edges/gaps, savannah, riparian vegetation, lowlands and gullies.

IMPACTS
Climbs over vegetation, forming tangled, impenetrable thickets, detrimental to fauna and to other flora. Has the ability to grow into forest and woodland canopies, causing canopy collapse. Also grows on to man-made structures, causing infrastructural damage. Mauritius thorn impedes operations in managed forestry plantations and is a fire hazard (Geldenhuys *et al*., 1986). In Hawaii, *C. decapetala* has invaded pastures, reducing their livestock carrying capacities and inhibiting the movement of livestock and people (Starr *et al*., 2003). The large spines on the stems can cause injuries to wildlife, livestock and people.

Caesalpinia decapetala (Roth) Alston

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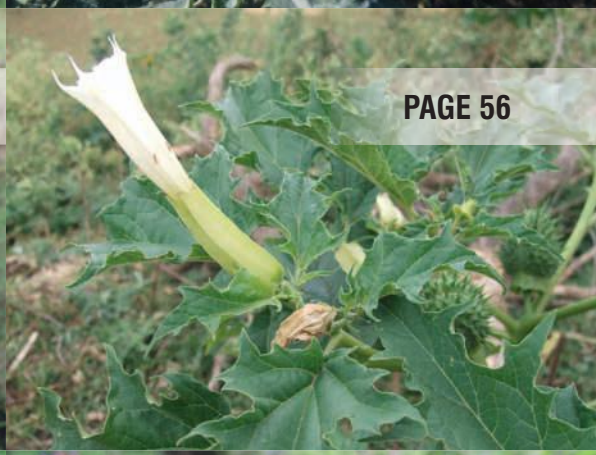
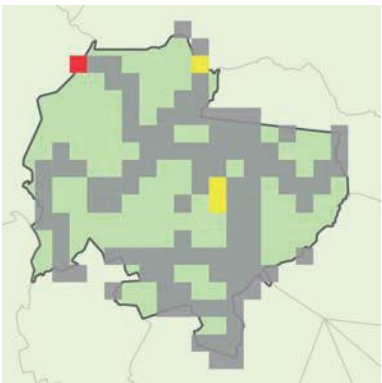


HERBS



DAISY FAMILY
Asteraceae

COMMON NAMES
English: goatweed, invading ageratum, Mexican ageratum,
Kikuyu: gathenge, Swahili: kimavi cha kuku, kundambara
Luhya: ilusa, Kisii: omonyaitira, Luo: oluoro-chieng
Kamba: mososoyiah

DESCRIPTION
Annual herb [0.3–1 (1.5) m tall] with fluffy flowerheads with green, purplish or reddish stems covered in short white hairs on young parts and nodes; shallow fibrous roots.

Leaves: Bright green, simple sparsely hairy, rough with prominent veins, triangular to egg-shaped (20–100 mm long and 5–50 mm wide), broader and rounded at the base with blunt or pointed tips, margins bluntly toothed, held in opposite pairs on stems, hairy leaf stalks (5–75 mm long); characteristic odour when crushed smelling like a male goat.

Flowers: Blue to lavender, sometimes with a white head in compact terminal flowerheads bearing 4–18 flower heads (4–5mm across and 4–6 mm long), with slender, hardly exserted styles as opposed to its congener *A. houstonianum* Mill. (also invasive elsewhere in Kenya), which has longer and thicker exserted styles in heads that are about 6–9 mm across; slightly aromatic.

Fruits: Achene (small, dry, one-seeded fruit that does not open at maturity), brown, hard.

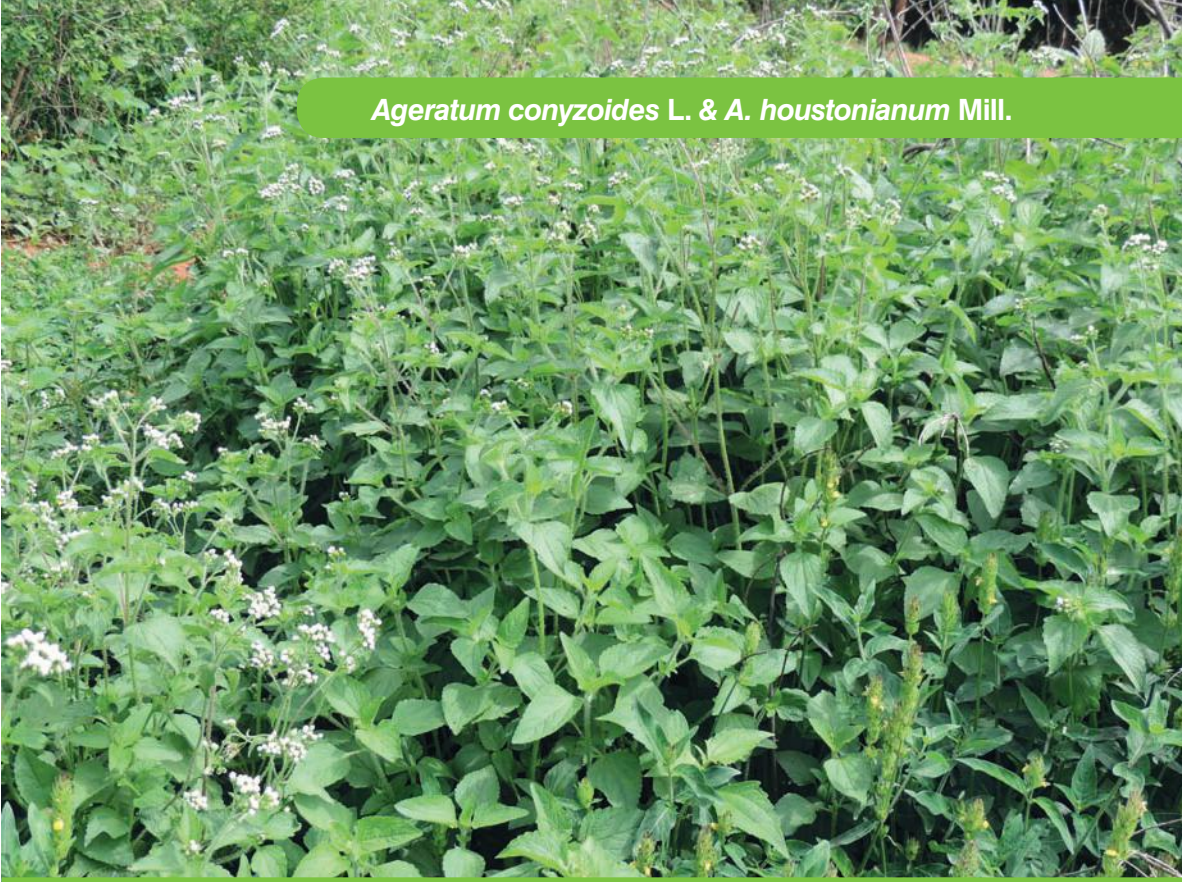
ORIGIN
Central and South America and West Indies.

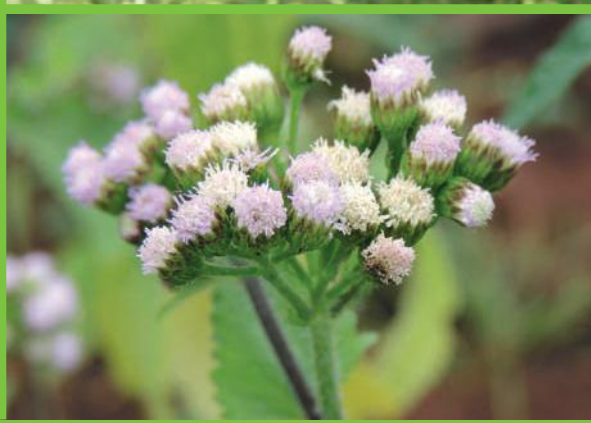
REASON FOR INTRODUCTION
Accidentally as a contaminant and ornament.

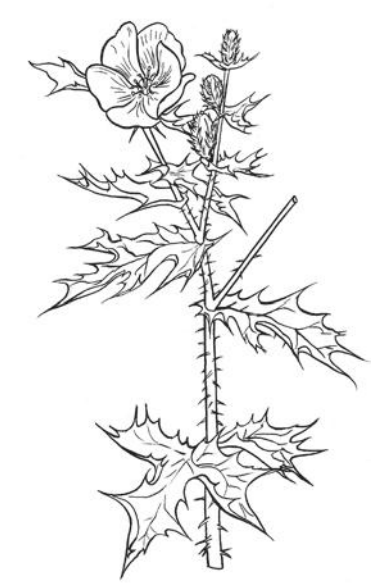
INVADES
Roadsides, railways, wasteland, disturbed land, fallow land, croplands, plantations, managed pasture, drainage ditches, forest edges/gaps, grasslands, natural pasture, riparian areas, lowlands, wetlands and coastal dunes.

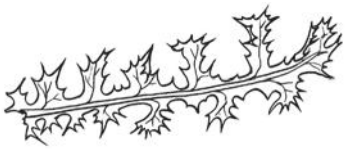
IMPACTS
Allelopathic, so inhibits the germination and growth of other plants and so readily displaces native plant species. Forming homogenous monospecific stands, it excludes native grasses and medicinally important plants, reducing native plant abundance (Dogra *et al*. 2009). In Hawaii, it threatens the survival of some native species, including *Brighamia insignis* Gray (Campanulaceae) (Centre for Plant Conservation, 2004).
A. conyzoides reduces crop yields, and is also an alternative host for a number of economically damaging crop pathogens and nematodes. In Tigray, northern Ethiopia, accidental consumption of the seeds with sorghum grains has been implicated in having caused the deaths, from liver disease, of 27 people and numerous livestock animals.

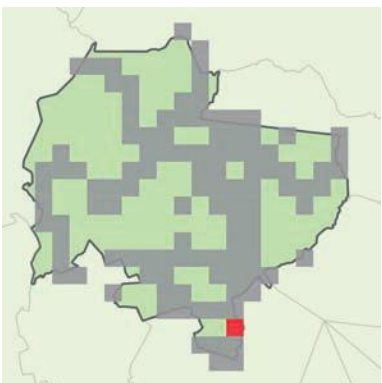
Ageratum conyzoides L. & *A. houstonianum* Mill.











POPPY FAMILY
Papaveraceae

COMMON NAMES

English: Mexican poppy, Mexican thistle, prickly poppy.

DESCRIPTION
Annual, very spiny herb (to 0.9 m high); stems exude a yellow sap when damaged.

Leaves: Bluish-green, with prominent white veins and yellow-midvein (5–22 cm long and 3–7 cm wide), deep lobed with sharp spines; leaves of *A. ochroleuca* are a lighter or greyer shade of green.

Flowers: Bright yellow (2.5–5 cm across) as opposed to pale yellow or creamy white in *A. ochroleuca*.

Fruits: Capsule (dry fruit that opens at maturity), spiny, green turning brown as they mature, egg-shaped (2.5–4 cm long), splitting into 3–6 lobes releasing small black seeds (1.5 mm across).

ORIGIN
Florida, Mexico, Belize, Costa Rica, El Salvador, Guatemala, Honduras, Nicaragua, Panama, Guyana, Venezuela, Brazil, Bolivia, Colombia, Ecuador, Peru, Paraguay, Uruguay and the Caribbean.

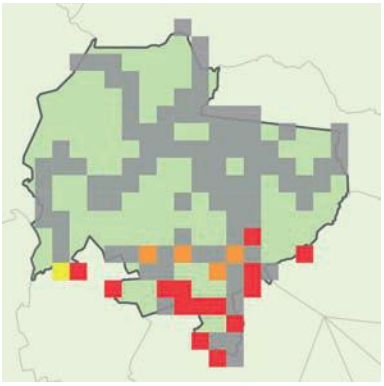
REASON FOR INTRODUCTION
Accidentally as a contaminant.

INVADES
Roadsides, railways, wasteland, disturbed land, urban open space, fallow land, crops, managed pasture, riparian areas, gullies and dry river courses.

IMPACTS
Reduces plant diversity and has an inhibitory effect on the germination and seedling growth of vegetables (Hazarika and Sannigrahi, 2001). Weed residues may also affect the growth and development of bambara groundnut and sorghum (Karikari *et al*. 2000). Ingestion of seeds by poultry can result in death and grazing animals can be poisoned if they consume contaminated hay or chaff. Harvesting of crops in the presence of this weed can also result in injuries. Edible vegetable oil either accidentally contaminated with *A. mexicana* or intentionally adulterated by unscrupulous traders has resulted in epidemic dropsy in India. An epidemic also occurred in South Africa following the contamination of wheat flour (Sharma *et al*., 1999). *A. mexicana* has been identified as an important allergen in India (Singh and Kumar, 2004).

Argemone mexicana L. & *A. ochroleuca* Sweet

Cirsium vulgare



DAISY FAMILY
Asteraceae

COMMON NAMES

English: black thistle, boar thistle, common thistle, green thistle, spear thistle.

DESCRIPTION
Spiny, living for one year but less than two, forming a large, flat rosette of leaves with much-branched stems (30–300 cm high), stems have spiny wings; deep tap root.

Leaves: Dark green above with stiff hairs, white woolly beneath, oval to somewhat elongated with almost parallel sides (4–30 cm long), deeply lobed with the lobes ending in sharp spines; young leaves entire, stalkless.

Flowers: Pink to mauve, in heads (to 5 cm long and 5 cm wide), surrounded by spiny bracts.

Fruits: Achene (small, dry, one-seeded fruit that does not open at maturity), tufted with silky hairs.

ORIGIN
Most countries in Europe, Algeria, Morocco, Tunisia, Afghanistan, Iran, Iraq, Turkey, Armenia, Azerbaijan, Georgia, Kazakhstan, Kyrgyzstan, Turkmenistan, Pakistan and China.

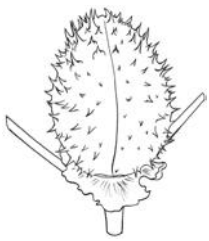
REASON FOR INTRODUCTION
Accidentally as a contaminant and bee forage.

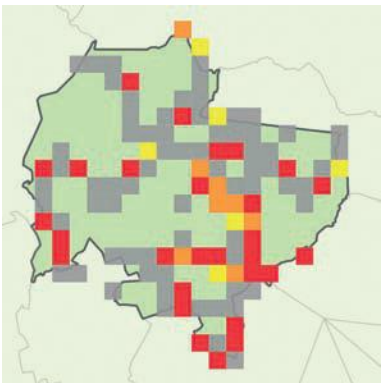
INVADES
Roadsides, disturbed land, wasteland, fallow land, managed pasture, drainage ditches, woodland, woodland gaps/edges, grasslands, savannah, lowlands and gullies.

IMPACTS
Can form dense stands which displace native plant species, reducing biodiversity. *C. vulgare* can also inhibit the growth of other plants (Holm *et al*., 1997). It has been found to reduce growth rates of seedlings of the ponderosa pine, *Pinus ponderosa* Douglas ex Lawson (Pinaceae) (Randall and Rejmánek, 1993), and to reduce fruit yields in orange groves in California, USA (Jordan, 1981). It reduces available forage in pastures, inhibits livestock movement, reduces wool quality, causes injury to animals (Auld *et al*., 1979; Forcella and Wood, 1986) and has little nutritional value for livestock (Holm *et al*., 1997). In Australia, the thistle has caused losses to the wool industry amounting to an estimated US$15 million a year (Davidson, 1990). In New Zealand, a negative correlation has been found between the live-weight gain in sheep and the density of *C. vulgare* (Hartley, 1983). The species is also an alternative host for a number of crop diseases (Fletcher, 1989; Weinbaum and Milbrath, 1976; Bitterlich and MacDonald, 1993). Its spiny leaves and bracts are responsible for transmitting viral diseases, including myxomatosis and scabby mouth, among animals (Parsons and Cuthbertson, 1992). Contact with the plant can cause physical injury and/or contact dermatitis (Dawe *et al*., 1996).

Cirsium vulgare (Savi) Ten.

Datura stramonium





DAISY FAMILY
Asteraceae

COMMON NAMES

English: common thorn apple, datura, devil's trumpet, jimson weed, moonflower, thorn apple; Kikuyu: gathumba, magurukia Taita: mwalola; Luhya: silulu; Kitosh: silulu; Luo: obala-ndagwa, koth kiyombi; Luganda: amaduudu; Ekegusii: omonyaitira; Swahili: muana; Kamba: ngwata; Kipsigis: barutu, chemogong

DESCRIPTION
Annual herb (0.5–2 m tall), stems green, purple or brown, hairy to hairless; single stem divides into two branches, each of which again divide into two branches as they grow, and so on.

Leaves: Dark green or purple, hairless, with prominent veins, egg-shaped with base broad and round to broadly triangular (5–25 cm long and 4–25 cm wide), margins coarsely and irregularly toothed or lobed; held alternate on stems on long leaf stalks (up to 10 cm); bad-smelling.

Flowers: White, mauve or purplish, funnel-shaped (up to 100 mm long) at each fork of the stem.

Fruits: Capsules (dry fruits that open at maturity), initially green turning brown as they mature, egg-shaped (3–7 cm long and 2–3.5 cm wide), covered with slender spines (up to 10 mm long) and held erect on the plant.

ORIGIN
Unclear but probably tropical America.

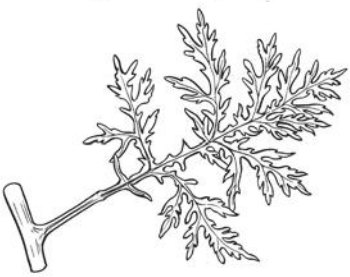
REASON FOR INTRODUCTION
Accidentally as a contaminant and ornament.

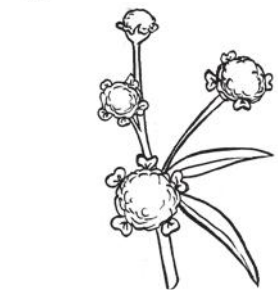
INVADES
Roadsides, railways, disturbed land, wasteland, fallow land, crops, managed pasture, drainage ditches, woodland edges/gaps, lowlands, gullies and dry riverbeds.

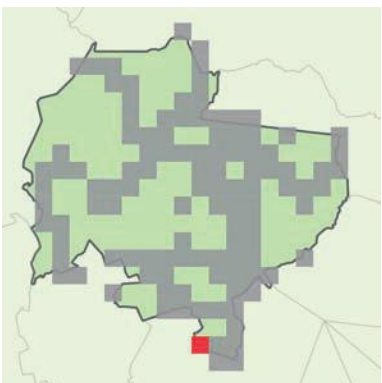
IMPACTS
Competes aggressively with native plants and crops, forming dense monospecific stands. Infestations in the USA have resulted in a 56% yield loss in cotton (Oliver *et al.*, 1991). Yields of soya bean plants growing at a distance of 1.2 m from a thorn apple plant are significantly reduced (Henry and Bauman, 1991), demonstrating the allelopathic impacts of this weed. In Spain, competition from thorn apple in irrigated maize has reduced yields by 56% (Torner *et al.*, 1995). At densities of 3–11 plants per m^2, yields of tomatoes may be reduced by 26–71% (Monaco *et al.*, 1981). *D. stramonium* is also an alternative host for several pests and pathogens of solanaceous crops. Toxic to people, horses, cattle, sheep, pigs and chickens (Watt and Breyer-Brandwijk, 1962), thorn apple has gained notoriety as a plant that is used by people to commit suicide. Between 1950 and 1965, 2,775 human deaths could be attributed to ingestion of this weed (Freye, 2009).

Datura stramonium

Parthenium hysterophorus







DAISY FAMILY
Asteraceae

COMMON NAMES

English: carrot weed, carrot grass, congress weed, famine weed, ragweed, white top.

DESCRIPTION
Annual erect herb, much branched [0.5–1.5 (–2) m high], forms a basal rosette of leaves when young, green stems are longitudinally grooved or ribbed and covered in short hairs.

Leaves: Pale green, covered with short stiff hairs; rosette and lower stem leaves are deeply divided and large (3–30cm long and 2–12 cm wide); upper stem leaves are shorter and less divided

Flowers: White, in small compact heads (5 mm across), clustered at the tips of branches, each flowerhead has five distinctive petals.

Fruits: Achenes (small, dry, one-seeded fruits that don't open at maturity), (1.5–2.5 mm long), five in each flowerhead.

ORIGIN
Mexico, Belize, Guatemala, Honduras, Bahamas, Barbados, Cuba, Dominica, Grenada, Haiti, Jamaica, Martinique, Puerto Rico, St. Vincent and the Grenadines, Trinidad and Tobago, the Virgin Islands, Guyana, Venezuela, Bolivia, Paraguay, Uruguay and Argentina.

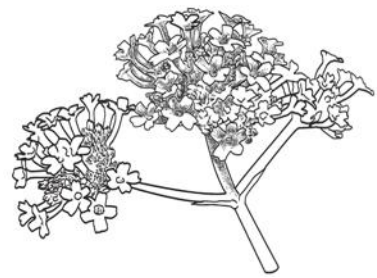
REASON FOR INTRODUCTION
Accidentally as a contaminant, medicine and ornament.

INVADES
Roadsides, railways, wasteland, disturbed land, fallow land, crops, plantations, managed pasture, gardens drainage ditches, forest edges/gaps, woodland edges/gaps, grassland, savannah, riversides, lowlands and gullies.

IMPACTS
Parthenium disrupts the ecology of grasslands, invades woodlands and generally disturbs native vegetation through aggressive competition (Evans, 1997). Being allelopathic, it inhibits the germination and growth of other plants, reducing crop yields and displacing palatable species in natural and improved pastures. *P. hysterophorus* is currently considered to be the most important weed in croplands and grazing areas by 90% of farmers in the lowlands of Ethiopia (Tamado and Millberg, 2000) with sorghum yields being reduced by 97% in experimental fields with high densities of *P. hysterophorus* (Tamado *et al*., 2002). In India, parthenium infestations have resulted in yield losses of up to 40% in several crops (Khosla and Sobti, 1979). Parthenium is also a secondary host for a range of crop pests. In terms of pasture production, this noxious weed has been found to reduce livestock carrying capacities by as much as 90% (Jayachandra, 1971). It also poses serious health hazards to livestock, and can cause severe allergenic reactions in people who regularly come into contact with the weed.

Parthenium hysterophorus L.

Verbena bonariensis



VERBENA FAMILY
Verbenaceae

COMMON NAMES

English: purple top, tall verbena

DESCRIPTION
Evergreen fast-growing herb (to 2 m high); stems are slender, square-shaped, rough and hairy; branches spread widely from main stem.

Leaves: Dark green, upper surface of leaves are coarsely hairy, oval to sword-shaped (7–10 cm long) with pointed tips, margins with forward-pointing sharp projections or teeth, held opposite each other on stems.

Flowers: Purple, bluish or lavender-pink, tubular, (2.5–3.5 mm long), clustered at the ends of stems; forming rounded clusters about 5–7 cm wide.

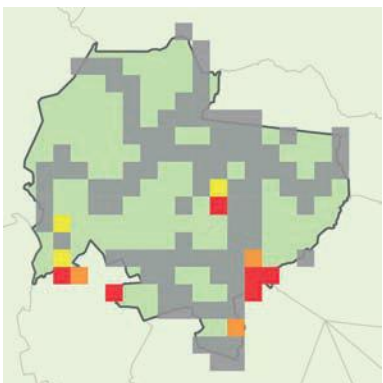
Fruits: "Nutlet," small, separate into four brown 'seeds' when mature.

ORIGIN
Brazil and Argentina

REASON FOR INTRODUCTION
Ornament.

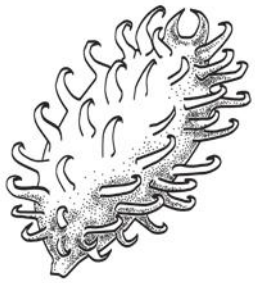
INVADES
Roadsides, disturbed land, drainage ditches, riversides, lowlands, forest edges/gaps, woodland edges/gaps and grasslands.

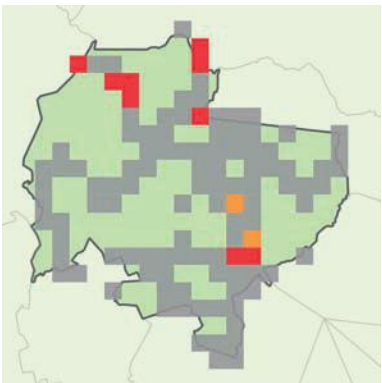
IMPACTS
Can form dense stands which may displace native plant and animal species. Reduces the livestock carrying capacities of pastures, and is said to cause abortion and sickness in cattle if consumed.



Verbena bonariensis L.

Xanthium strumarium





DAISY FAMILY
Asteraceae

COMMON NAMES

English: large cocklebur, noogoora bur, sheep bur

DESCRIPTION
Annual, much-branched herb with erect stems (20–150 cm high) without spines; stems stout, green, brownish or reddish-brown, roughly hairy.

Leaves: Green, paler below, hairy on both surfaces, broadly egg-shaped to triangular (2–8 cm long), margins irregularly toothed or lobed, on long leaf stalks (2–8 cm), held alternately on stems.

Flowers: Green, inconspicuous, in the leaf axils.

Fruits: Burrs, green turning yellowish then brown as they mature (1.5–2.5 cm long), covered with hooked spines (up to 20 mm long) and two terminal beaks.

ORIGIN
Uncertain, but probably Central and South America.

REASON FOR INTRODUCTION
Bee forage and a contaminant.

INVADES
Roadsides, wasteland, disturbed land, fallow land, crops, plantations, drainage ditches, savannah, water courses, lowlands, floodplains and sandy and dry riverbeds.

IMPACTS
Rapidly forms large stands, displacing other plant species. *X. strumarium* is a major weed of row crops such as soya beans, cotton, maize and groundnuts in many parts of the world, including North America, southern Europe, the Middle East, South Africa, India and Japan (Webster and Coble, 1997). It also has a damaging impact on rice production in Southeast Asia (Waterhouse, 1993). In the USA, high-density cocklebur infestations have resulted in soya bean yield losses of as much as 80% (Stoller *et al*., 1987; Rushing and Oliver, 1998). Infestations can also decrease soya bean seed quality and harvesting efficiency (Ellis *et al*., 1998). Even low-density cocklebur infestations in cotton fields in the USA have contributed to seed yield losses of 60–90 kg per hectare, or approximately 5% (Snipes *et al*., 1982). Cocklebur has also caused yield losses in groundnuts of 31–39% and 88% at low and high densities, respectively, in the southern USA (Royal *et al*., 1997). *X. strumarium* burs lodge in animal hair and in sheep's wool, reducing the quality and increasing treatment costs (Wapshere, 1974; Hocking and Liddle, 1986). The plants are toxic to livestock and can lead to death if eaten (Weaver and Lechowicz, 1982). Cocklebur is also an alternative host for a number of crop pests (Hocking and Liddle, 1986).

Xanthium strumarium L.

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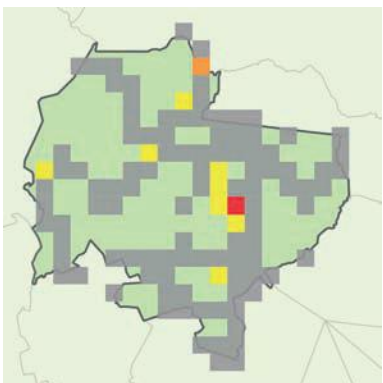
SHRUBS

Catharanthus roseus



DOGBANE FAMILY
Apocynaceae

COMMON NAMES

English: Madagascar periwinkle, rosy periwinkle

DESCRIPTION
Evergreen, erect herb or sub-shrub (30–100 cm high), woody at the base, much branched green or dark red stems which are cylindrical and longitudinally ridged or narrowly winged; white latex.

Leaves: Bright green and glossy with a prominent midvein, usually hairy, sometimes hairless, egg-shaped but narrower at base (40–80 mm long and 10–30 mm wide); leaf tip is blunt with a tiny point extending from the midrib; short leaf stalk (2.5–9 cm long).

Flowers: Pink or white, solitary or paired borne in the upper angle between the leaf stalk and stem of the upper leaves.

Fruits: Follicles (dry fruit with one compartment and opens along one side at maturity) which can easily mistaken for unopened flower buds, green, cylindrical (2–4.7 cm long and 3 mm wide); could be mistaken for uopened flower buds.

ORIGIN
Madagascar

REASON FOR INTRODUCTION
Medicine and ornament.

INVADES
Roadsides, disturbed land, wasteland, drainage ditches, woodland edges/gaps, savannah, rocky outcrops, lowlands, gullies and coastal scrub.

IMPACTS
Rosy periwinkle can form dense stands which are detrimental to native plant species. It does particularly well in dry savannah areas. It is unpalatable to livestock and wildlife. On the Aldabra atoll, it dominates the low ground vegetation and is not consumed by tortoises (IUCN, undated) probably because it is highly toxic. Repeated oral administration of *C. roseus* leaf extracts caused mortality and diarrhoea in rats after few days of treatment (Kevin *et al*., 2012).

Catharanthus roseus (L.) Don

Cestrum aurantiacum

TOMATO FAMILY
Solanaceae

COMMON NAMES

English: orange cestrum, orange jessamine, yellow cestrum.

DESCRIPTION

Evergreen, much-branched, half-climbing shrub [1–2 (–6m) high], sparsely hairy stems and leaves; stems and leaves bruise easily, emitting an unpleasant smell.

Leaves: Light green, hairless, oval to egg-shaped (7–13 cm long and 2.5–7 cm wide), leaf stalk 1–4 cm long.

Flowers: Orange-yellow, tubular (17–21 mm long), 10–15 in axillary and terminal clusters.

Fruits: Berries (fleshy fruits that don't open at maturity), white, spongy, round, small (10 mm across).

ORIGIN

Guatemala and probably elsewhere in Central America.

REASON FOR INTRODUCTION

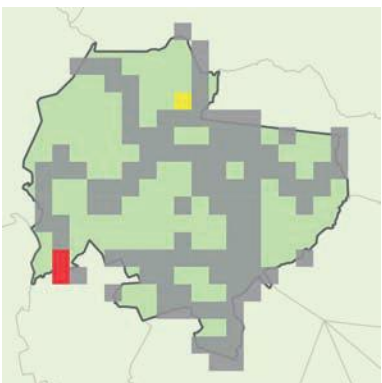
Hedge/barrier and ornament.

INVADES

Roadsides, disturbed land, plantations, drainage ditches, forest edges/gaps, woodlands, savannah, riversides and gullies.

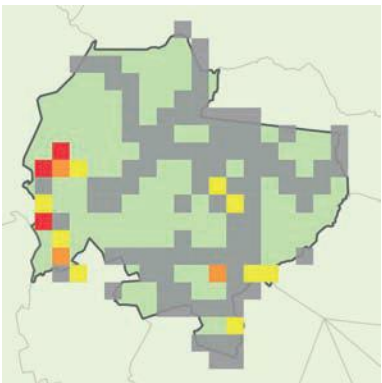
IMPACTS

Readily 'climbs' into trees and over shrubs, smothering native vegetation and impoverishing biodiversity. In Kenya, *C. aurantiacum* has invaded more than 4,000 hectares of the Cherangani Forest, displacing valuable forage species. It is toxic to people and to livestock and has caused numerous cattle deaths. Cattle which have consumed the plant become tetchy, before becoming paralysed and dying. The unripe berries are also fatal if consumed by sheep, while the leaves lead to non-fatal poisoning (Fuller and McClintock, 1986). According to the community in the Cherangani Forest, the species has also had a negative impact on bee populations.



Cestrum aurantiacum Lindl.

Euryops chrysanthemoides



DAISY FAMILY
Asteraceae

COMMON NAMES

English: African bush daisy, daisy-bush, golden daisy, Paris daisy.

DESCRIPTION
Evergreen, bushy shrub (0.5–2 m tall), with tender and well branched stems.

Leaves: Deep green, hairless, glossy with greyish hairy undersides, narrowly oval to egg-shaped with the narrower end at the base (3.5–8 cm long and 1–2 cm wide) with 7–9 deeply indented 'lobes', held alternately on stems at the ends of branches; occasional tufts of woolly hairs where the leaf stalk of younger leaves meets the stem.

Flowers: Bright yellow daisy-like flowers (3–4 cm wide), solitary or several on branch tips, borne on long stalks (10–15 cm long).

Fruits: Achenes (small, dry, one-seeded fruits that don't open at maturity), black, ribbed (0.5 mm long).

ORIGIN
South Africa, Lesotho and Swaziland.

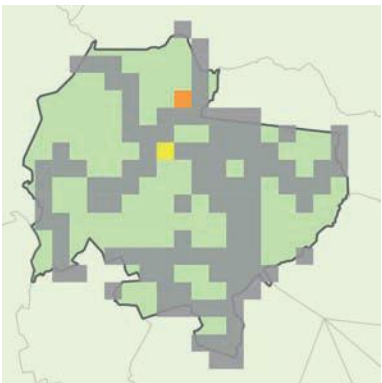
REASON FOR INTRODUCTION
Hedge/barrier and ornament.

INVADES
Roadsides, disturbed areas, gardens, urban open space and forest edges/gaps.

IMPACTS
Forms dense monospecific stands which may displace native plants and associated animal species. Seeds easily and shades out other plants.

Euryops chrysanthemoides (DC.) Nord

Jatropha gossypiifolia



SPURGE FAMILY
Euphorbiaceae

COMMON NAMES

English: American purging nut, bellyache bush, red fig-nut flower, red physic nut, wild cassava.

DESCRIPTION
Evergreen, erect shrub [1–3 (4) m tall]; older stems are thick and succulent-like; young branches are purplish and hairy; young shoots exude a brownish latex when damaged.

Leaves: Reddish-brown to dark bronze or purplish turning bright green with age, hairless, simple (4.5–10 cm long and 5–13 cm wide), usually with 3 or 5 deep lobes, 3–5 veins from the base, margins glandular and minutely toothed; leaf stalks are 6–9 cm long and covered in sticky hairs.

Flowers: Five dark red or deep purple petals with yellow centre, borne in branched clusters (8–15 cm long) at the tips of branches.

Fruits: Capsules (dry fruits that opens at maturity), glossy green turning brown as they mature, three-lobed, slightly hairy, somewhat elongated with almost parallel sides to almost round (about 12 mm long and 10 mm wide), containing three large light brown seeds.

ORIGIN
Antigua and Barbuda, Dominica, Guadeloupe, Puerto Rico, St. Kitts and Nevis, St. Lucia, Mexico, Costa Rica, Honduras, Nicaragua, Venezuela, Brazil, Bolivia, Colombia, Ecuador, Peru and Paraguay.

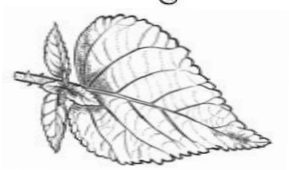
REASON FOR INTRODUCTION
Medicine, natural oils, hedge/barrier and ornament.

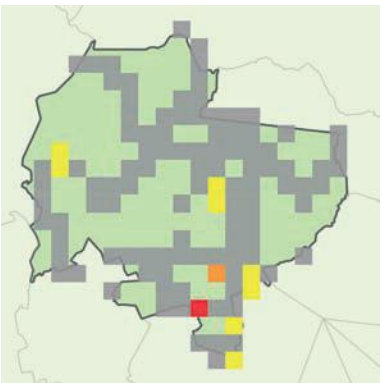
INVADES
Roadsides, disturbed areas, urban open space, drainage ditches, savannah, lowlands, gullies and dry riverbeds.

IMPACTS
This weed forms dense thickets, especially in riparian areas where it readily displaces native plant species and prevents their regeneration. It also significantly reduces livestock carrying capacities outcompeting valuable forage species. Although the plant is not consumed by livestock, accidental ingestion does occur. In 1995 in northern Queensland, Australia, 312 head of livestock died (290 cattle, 7 horses and 15 goats) after accidentally consuming the plant during a drought (Csurhes, 1999).

Jatropha gossypiifolia L.

Lantana camara





VERBENA FAMILY
Verbenaceae

COMMON NAMES

English: curse of India, lantana, Spanish flag, tickberry, prickly lantana; Swahili: mvepe; Taita: mwemberi; Tugen: sekechewo; Kamba: muvisavisi; Kikuyu: mukenia; Kipsigis: bek ap tarit; Maasai: lukurman-oonkayiok, olmagirigiriani; Nandi: petiapteriet, pipterit; Luhya: lumenenambuli; Luo: magwagwa, nyamridhi, obengele

DESCRIPTION

Compact, untidy long-lived shrub/scrambler (up to 2 m or higher), forming dense thickets; stems are usually green turning grey or brown with age, square in cross-section with short hairs and hooked/recurved prickles/thorns.

Leaves: Dark green, rough hairy, simple, egg-shaped (2–13 cm long and 1.5–7 cm wide) with pointed tips, margins toothed/rough, wrinkled appearance, held opposite each other on stems, smell strongly when crushed.

Flowers: Small red, pink, crimson, orange, yellow or white flowers borne in dense clusters (2–4 cm) across, with each cluster containing about 20–40 flowers; clusters on stalks (2–10 cm long); individual flowers are tubular (9–14 mm long and 4–10 mm across).

Fruits: Berries (fleshy fruits that don't open at maturity), initially shiny green turning purplish-black when mature (5–8 mm across), one-seeded.

ORIGIN

Mexico, Bahamas, Cuba, Hispaniola, Jamaica, Costa Rica, Venezuela and Colombia.

REASON FOR INTRODUCTION

Hedging/barrier and ornament

INVADES

Roadsides, railways, disturbed land, wasteland, plantations, managed pasture, drainage ditches, forest edges/gaps, woodland edges/gaps, grassland, savannah, water courses, lowlands and gullies.

IMPACTS

Lantana forms dense, impenetrable thickets, reducing biodiversity. In Australia, Turner and Downey (2010) identified 275 native plant species and 24 native animal species which are threatened by lantana. In Southeast Asia, lantana both reduces yields and increases management costs incurred by growers of durian, pineapples, bananas and rubber (Waterhouse, 1993). Lantana is also toxic, causing pastoral losses of A$ 7.7 million in Queensland, Australia, in 1985 which included 1,500 animal deaths, reduced productivity, loss of pasture and control costs (van Oosterhout, 2004). In South Africa, lantana accounts for about 25% of all reported cases of livestock poisoning by plants (Wells and Stirton, 1988). There have even been recorded fatalities in people, especially children, after consuming the green fruit. Lantana can also alter fire regimes.

Lantana camara L.

Mirabilis jalapa

FOUR O'CLOCK FAMILY
Nyctaginaceae

COMMON NAMES

English: beauty of the night, false jalap, four o'clock flower, marvel of Peru.

DESCRIPTION
Evergreeen herb or shrub (0.5–2 m high); stems are erect with multiple spreading branches; roots are tuberous.

Leaves: Dark green, simple, egg-shaped (3–10 cm long) with a broad and round base and a pointed tip; held opposite each other on stem, leaf stalk is about 4 cm long.

Flowers: White to red, yellow or striped, tubular or trumpet-like, five-lobed (6.5 cm long and 3.5 cm wide), single but sometimes borne in clusters of 3–7, fragrant.

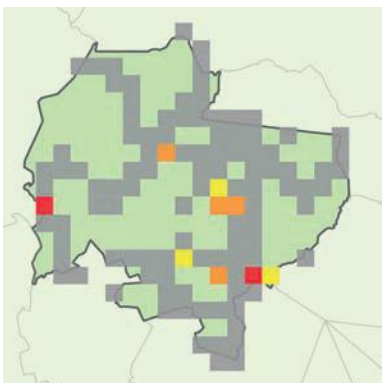
Fruits: Capsules (dry fruits that open at maturity), tiny.

ORIGIN
Peru

REASON FOR INTRODUCTION
Ornament

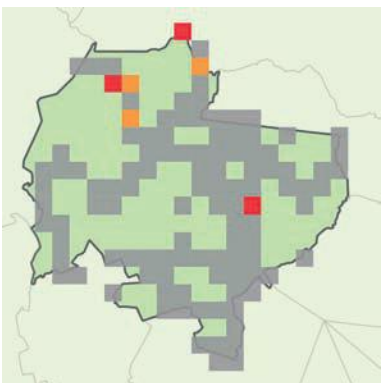
INVADES
Roadsides, disturbed areas, wasteland, drainage ditches, edges of irrigation channels, lowlands, riversides, swamps and gullies.

IMPACTS
Forms dense stands which displace native plant species, especially in areas with sufficient soil moisture. Being allelopathic, *M. jalapa* inhibits the germination and growth of other plant species (Zhou *et al*., 2008). Both the roots and the seeds are poisonous, and their consumption can cause gastroenteritis in children (Lewis, 2003). May also be toxic to wildlife.



Mirabilis jalapa L.

Senna occidentalis



PEA FAMILY
Fabaceae; subfamily: Caesalpinaceae

COMMON NAMES

English: ant bush, arsenic bush, coffee senna, sicklepod, stinkweed.

DESCRIPTION
Annual or lives for more than one year but less that two, erect herb or shrub (0.5–2.5 m tall); stems reddish-purple, smooth, hairless or sparsely hairy, four-angled or grooved when young becoming greenish-brown and rounded.

Leaves: Green, once-divided (15–20 cm long), with 3–5 pairs of oppositely held egg-shaped or oval leaflets with broad and rounded bases, tapering towards the end (3–10 cm long and 2–3 cm wide) with pointed tips; conspicuous gland at the base of each leaf stalk; alternately held on stems on reddish stalks (3–5 cm long).

Flowers: Bright yellow (20–30 mm across) in small clusters of 2–6 flowers in forks of uppermost leaves.

Fruits: Pods (several-seeded dry fruit that splits open at maturity), green turning brown as they mature, flattened, slightly curled (75–130 mm long and 8–10 mm wide), held upright.

ORIGIN
Belize, Cayman Islands, Costa Rica, Dominican Republic, El Salvador, Guatemala, Haiti, Nicaragua, Panama Argentina, Bolivia, Brazil, Ecuador, French Guiana, Guyana, Peru, Suriname and Venezuela.

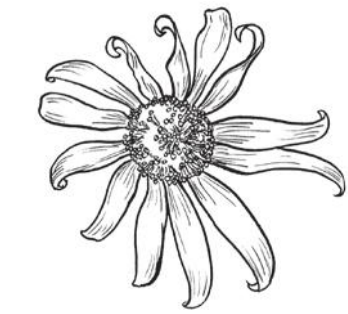
REASON FOR INTRODUCTION
Coffee substitute, medicine and ornament.

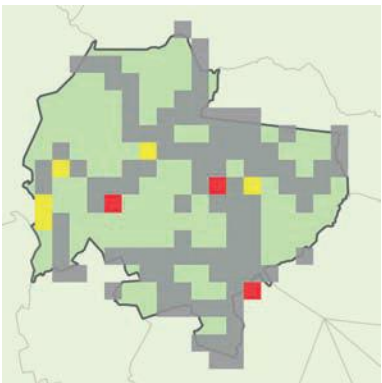
INVADES
Roadsides, wasteland, disturbed land, fallow land, managed pastures, drainage ditches, woodland edges/gaps, savannah, riparian vegetation and gullies.

IMPACTS
Dense stands can displace native plant species, and reduce livestock carrying capacities in managed and natural pastures. Being allelopathic, it inhibits the germination and growth of other plants. Studies have shown that it has a negative impact on maize (Arora, 2013) and cotton yields (Higgins *et al*., 1986) and is an alternative host for crop diseases (Suteri *et al*., 1979). The seeds of *S. occidentalis* are highly toxic, containing compounds that damage the liver, the vascular system and the heart and lungs of domestic livestock, often leading to death in cattle (Barros *et al*., 1999), horses (Riet-Correa *et al*., 1998), goats (Suliman *et al*., 1982; Suliman and Shommein, 1986), pigs (Martins *et al*., 1986), poultry (Haraguchi *et al*., 1998), and rabbits (O'Hara and Pierce, 1974). Consumption of the seeds in western Uttar Pradesh, in India, resulted in the deaths of nine children within 5 days (Vashishtha *et al*., 2007).

Senna occidentalis (L.) Link

Tithonia diversifolia





DAISY FAMILY
Asteraceae

COMMON NAMES

English: Mexican sunflower, shrub sunflower, tree marigold
Embu: kirurite
Kamba: ila, mulaa
Kikuyu: maruru
Kisii: amaua amaroro
Luhya: kamaua liming'ulie, maua amalulu
Luo: akech, maua makech, maua madongo, mauwa
Teso: emaua

DESCRIPTION

Annual or evergreen herbaceous shrub, woody at the base [2–3 (–5) m high]; stems slightly ridged and hairy when young.

Leaves: Greyish-green, finely hairy on underside giving a grey appearance, simple (6–33 cm long and 5–22 cm wide) with 3–5 (–7) pointed lobes, margins with a series of curved projections or teeth; held opposite or alternately on stem.

Flowers: Bright yellow, daisy or sunflower-like (up to 10 cm across), held on long and swollen stalks (7–30 cm long) which are velvety below the flowerhead.

Fruits: Achenes (small, dry, one-seeded fruits that don't open at maturity), brown (4–8 mm long), in a brown spiky mass.

ORIGIN

Mexico, Belize, Costa Rica, El Salvador, Guatemala, Honduras, Nicaragua and Panama.

REASON FOR INTRODUCTION

Fodder, medicine, mulch, soil improvement, hedge/barrier and ornament.

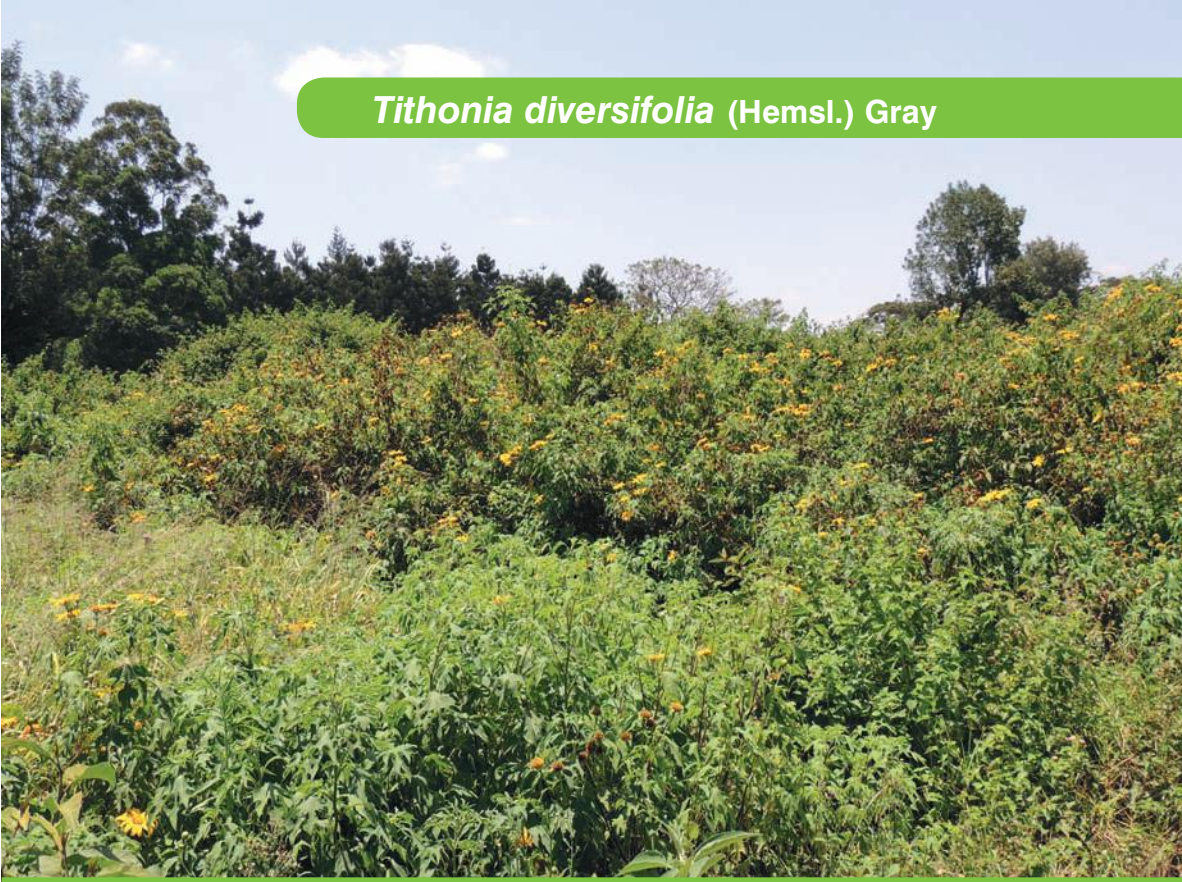
INVADES

Roadsides, disturbed sites, wastelands, urban open space, fallow land, savannah, lowlands and riparian vegetation.

IMPACTS

Forms dense stands displacing native plant species and the animals associated with them. *T. diversifolia* is displacing native species in the wetlands of the Apete River, Eleyele Lake and Oba Dam in Ibadan, Nigeria, including the invasive and aggressive shrub *Chromolaena odorata* (Oluode *et al*., 2011), and is now considered to be one of the most invasive species in Nigeria (Borokini, 2011). Mexican sunflower has the ability to compete with agricultural crops (Illori *et al*., 2010) and is contributing to the extinction of local species, including important medicinal plants (Oludare and Muoghalu, 2014). According to reports, it is leading to the abandonment of farms in the Copperbelt region of Zambia.

Tithonia diversifolia (Hemsl.) Gray

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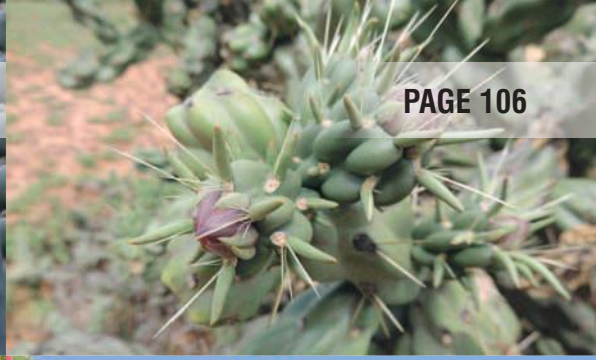
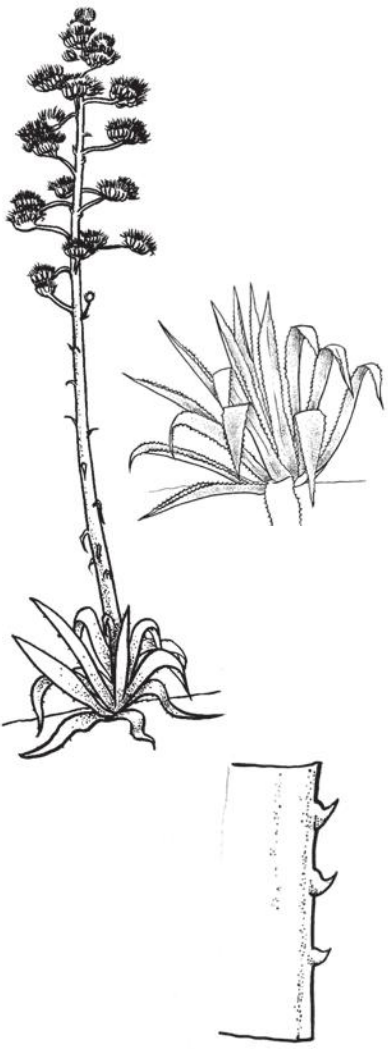


SUCCULENTS

Agave americana



SISAL FAMILY
Agavaceae

COMMON NAMES

English: American agave, American aloe, century plant.

DESCRIPTION
Succulent shrub (1–2 m high and 2–4 m across), with large leaves originating from a basal rosette with a flowering pole (5–12 m tall); does not produce plantlets (bulbils) on flowering pole.

Leaves: Greyish-green, long and narrow, sword-shaped leaves (1–2 m long and 15–25 cm wide), margins lined with sharp spines (up to 1 cm long) and a terminal leaf spine (3–5 cm long); variegated forms have grey to dark green leaves with yellow or white margins or central stripe; leaves erect at first, then becoming reflexed, flopping over to one side in the case of *A. americana* ssp. *americana* var. *americana*, but remaining erect to stiffly spreading in *A. americana* ssp. *americana* var. *expansa*.

Flowers: Pale yellow (7–10 cm long), borne on flowering pole or stem.

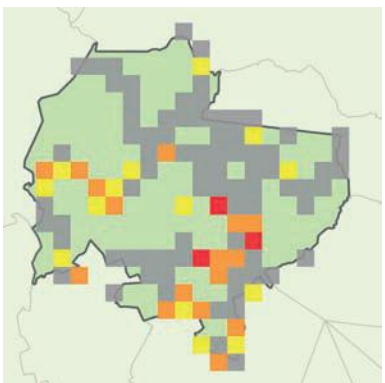
Fruits: Capsules (dry fruits that open at maturity), green turning brown or black as they mature, large (4–5 cm long) with pointed tips.

ORIGIN
Mexico and southern USA

REASON FOR INTRODUCTION
Flowering poles used in construction, fibre, hedge/barrier and ornament.

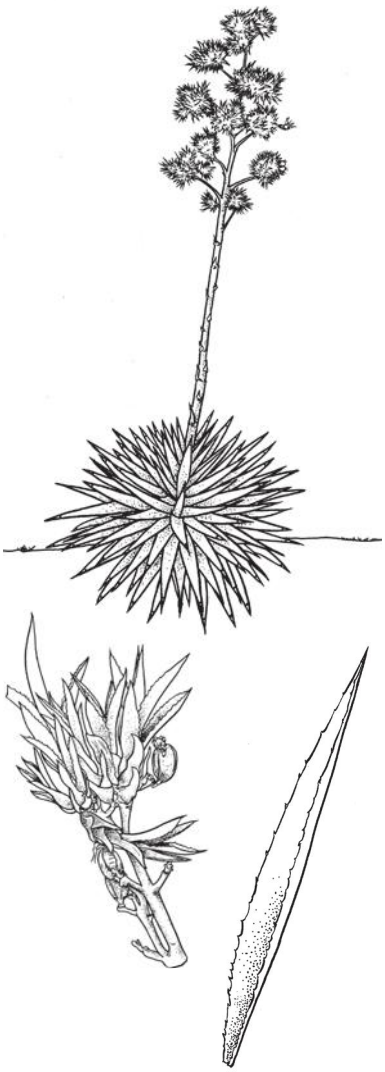
INVADES
Disturbed land, urban open space, drainage ditches, savannah, rocky outcrops and lowlands.

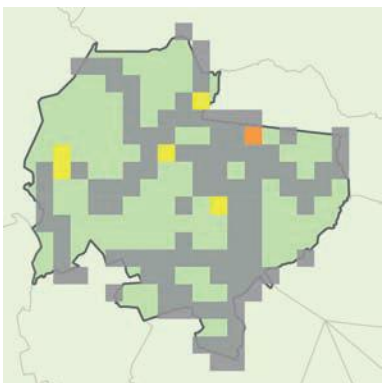
IMPACTS
Spreads by suckering from the root crown, allowing one plant to form a dense impenetrable stand over time, to the detriment of native plant species. Studies in Spain have shown that invaded areas harbour fewer native species than uninvaded areas (Badano and Pugnaire, 2004). The sharp spines can injure people and animals, and may also restrict the movement of animals and reduce the abundance of forage species. Contact with the fresh sap can cause dermatitis and/or digestive problems in people. Sap from the spines and the leaf tips may enter the skin through puncture wounds, which can become infected.



Agave americana L.

Agave angustifolia





SISAL FAMILY
Agavaceae

COMMON NAMES

English: Caribbean agave, century plant

DESCRIPTION
Medium-sized evergreen succulent shrub with leaves originating from a basal rosette with a branched flowering pole (3–5 m tall); basal suckers; produces numerous plantlets (bulbils) on flowering pole.

Leaves: Light green to pale bluish-green or greyish, linear to sword-shaped (0.6–1.2 m long); margins armed with vicious small teeth (2–5 mm long) and a terminal leaf spine (1.5–3.5 cm long).

Flowers: Green to yellow, erect (5–6.5 cm long) in branched clusters along flowering pole.

Fruits: Capsules (dry fruits that open at maturity), green turning brown as they mature, egg-shaped (3–5 cm long).

ORIGIN
Mexico, Belize, Costa Rica, El Salvador, Guatemala, Nicaragua and Honduras.

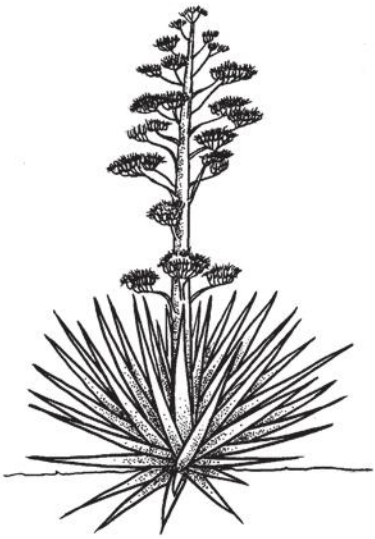
REASON FOR INTRODUCTION
Fibre, hedge/barrier and ornament.

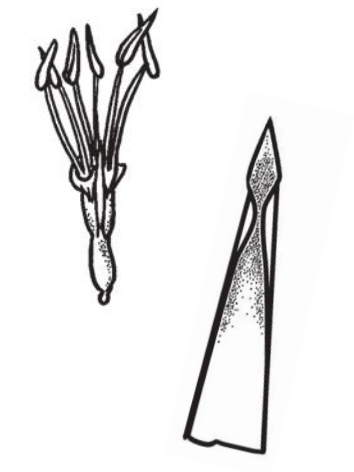
INVADES
Roadsides, wasteland, disturbed land, urban open space, plantations, drainage ditches, woodland gaps/edges, savannah, lowlands and gullies.

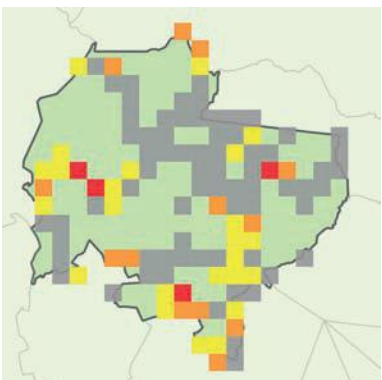
IMPACTS
Has escaped from cultivation and established dense stands to the detriment of native plant species. Stands also inhibit or prevent the free movement of people, livestock and wildlife and can cause injury. Other impacts are similar to those recorded for *A. americana* and other congeners.

Agave angustifolia Haw.

Agave sisalana







SISAL FAMILY
Agavaceae

COMMON NAMES

English: sisal, sisal hemp, hemp plant
Swahili: katani, mkonge
Kamba: ikonge
Taita: ikonge
Luhya: likongo

DESCRIPTION
Medium-sized to large succulent shrub with thick, sword-shaped leaves originating from a basal rosette with a branched flowering pole (5–6 m high); suckers from the base through elongated rhizomes; produces numerous plantlets (bulbils) on flowering pole.

Leaves: Dark green, linear or sword-shaped (0.9–1.3 m long), margins smooth, rarely toothed with terminal spine (2–2.5 cm long).

Flowers: Greenish yellow, erect (4–6 mm long), with reddish filaments up to 6 cm long, in branched clusters along flowering pole.

Fruits: Rare to none, if capsules present (6 cm long and 2–2.5 cm wide) usually with no seeds.

ORIGIN
Mexico

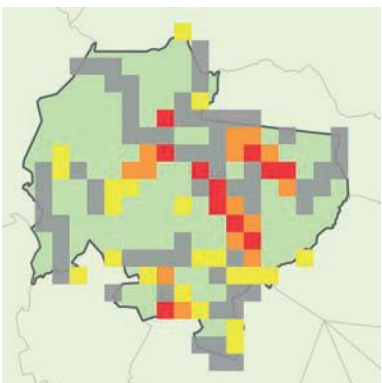
REASON FOR INTRODUCTION
Flowering poles used in construction, fibre, bee forage, hedge/barrier and ornament.

INVADES
Disturbed land, wasteland, urban open space, plantations, drainage ditches, savannah, lowlands and gullies.

IMPACTS
Suckering abundantly from the base which means that it can spread without reproduction from seeds. Also has bulbils which can contribute to spread. Out-competes and displaces native plants in semi-arid and arid environments, through more efficient exploitation of water and nutrients. *A. sisalana* often escapes from plantations into adjacent natural habitats, where it may form dense monospecific stands (Badano and Pugnaire, 2004). It threatens biodiversity at the UNESCO World Heritage Site of Aldabra Atoll in the Seychelles (van Dinther *et al*., 2015). In Madagascar, sisal has invaded inselbergs, posing a serious threat to the indigenous vegetation (Porembski, 2000). Sisal also depletes soil fertility and reduces the pH of soils (Hartemink *et al*., 1996).

Agave sisalana Perrine

Austrocylindropuntia subalata



CACTUS FAMILY
Cactaceae

COMMON NAMES

English: Colville cactus, devil's rope, long-spine cactus

DESCRIPTION
Succulent, spiny, much-branched shrub [3–4 (–5) m tall], elongated (up to 0.5 m long) branches green or pale bluish-green with small wart-like swellings or humps, armed with straight and strong white spines [(1–) 2–4 (–13) cm long].

Leaves: Green, conspicuous (4–8 cm long), persistent.

Flowers: Purple-pink (up to 6 cm long), found at tips of segments, showy.

Fruits: Berries (fleshy fruits that don't open at maturity), green turning yellow-green as they mature, fleshy, large, egg-shaped to elongated, often in chains; yellow-brown seeds, mostly sterile.

ORIGIN
Bolivia and Peru

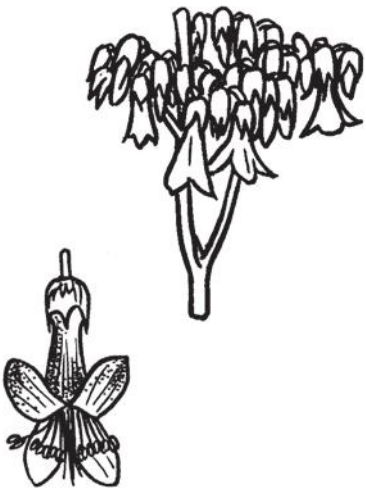
REASON FOR INTRODUCTION
Hedge/barrier and ornament

INVADES
Roadsides, disturbed land, wastelands, drainage ditches, grasslands, savannah, riversides and sandy stream beds.

IMPACTS
Forms impenetrable thickets wherever it has been planted, and establishes readily from broken stem segments on riverbanks and in drainage ditches and gullies, particularly after heavy rains. Such thickets prevent access to grazing pastures and water resources. Infestations reduce the livestock carrying capacities of pastures and block the movement of wild animals. The spines cause injuries to livestock, wildlife and people, and in some cases infestations have led to the abandonment of farmlands. Additional impacts are assumed to be similar to those recorded for other invasive cactus species.

Austrocylindropuntia subalata (Muelenpf.) Backeb.

Bryophyllum daigremontianum



STONECROP FAMILY
Crassulaceae

COMMON NAMES

English: alligator plant, devil's backbone, maternity plant

DESCRIPTION
Evergreen, erect and succulent herb (0.3–1m high), with a purplish appearance; stems stout and mostly unbranched.

Leaves: Purple blotched on lower surface, green above, simple, triangular sword-shaped (5–25 cm long and 0.5–2 cm wide) with pointed tips, margins with forward-pointing sharp projections or teeth, with plantlets (bulbils) forming on leaf notches; leaves held opposite each other on stem and evenly spaced.

Flowers: Purple-orange with yellow margins, tubular, pendulous.

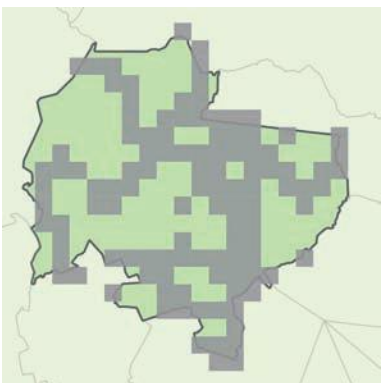
Fruits: Follicles (dry fruits having one compartment that opens, along one side only, at maturity), papery and membranous containing thousands of tiny somewhat elongated, longitudinally ridged seeds (0.6–1 mm long and 0.2–0.3 mm wide).

ORIGIN
Madagascar

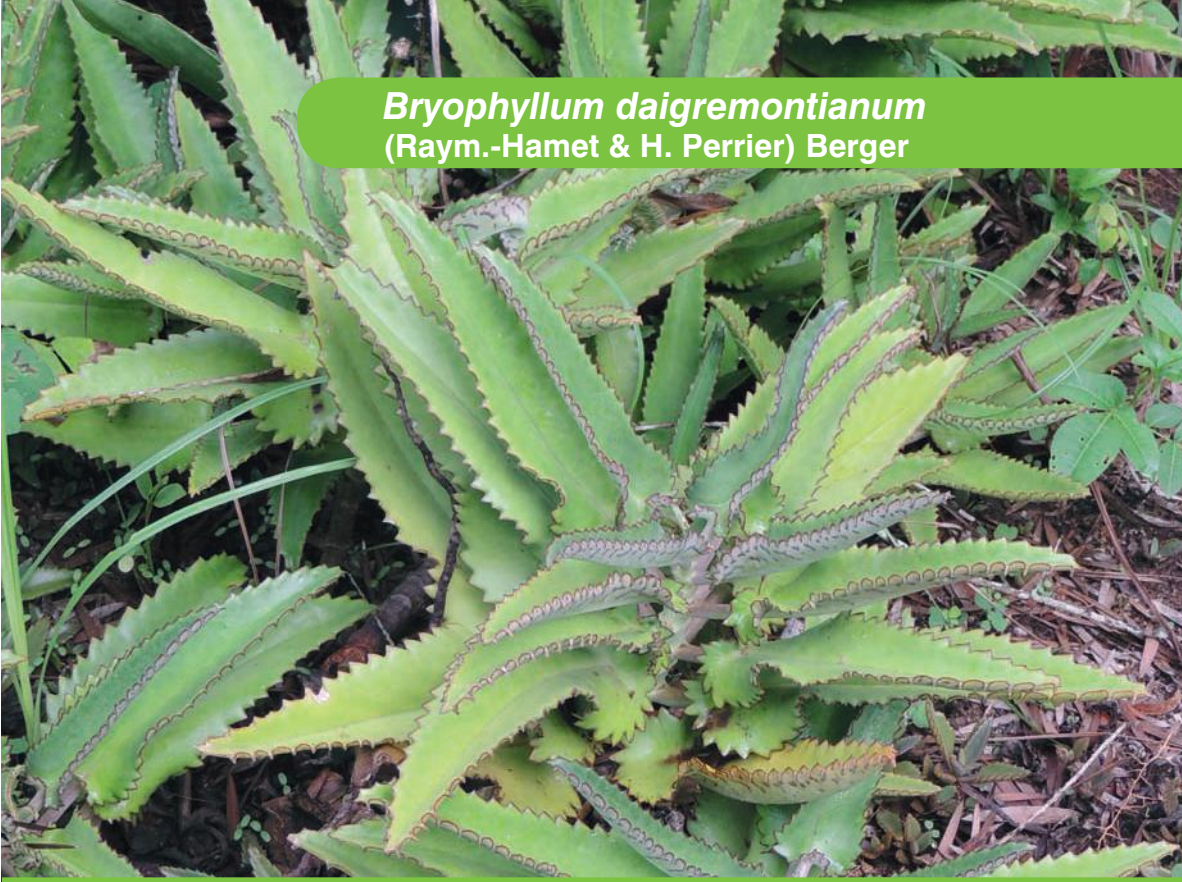
REASON FOR INTRODUCTION
Ornament

INVADES
Disturbed land, gardens, drainage ditches, gullies, savannah especially rocky ridges and outcrops.

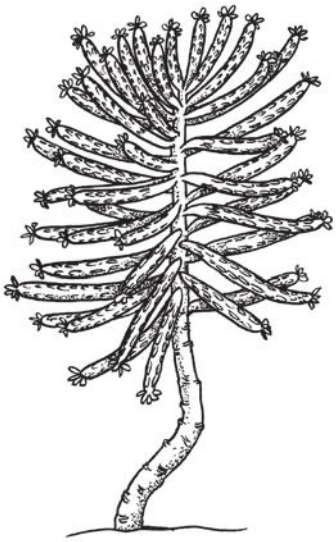
IMPACTS
Can form dense monospecific stands which displace plants of other species. Being allelopathic, it inhibits the germination and growth of other plants. It also has the potential to alter soil properties (Chacón *et al*., 2009) and to inhibit the regeneration of native vegetation (Groner, 1975; Herrera *et al*., 2011). It is also highly toxic, and cases of cardiac glycoside poisoning have been reported in calves that were fed flowerheads in trials (McKenzie *et al*., 2008). Several *Bryophyllum* species, including the hybrid *B. daigremontianum* × *Bryophyllum delagoense* are known to have caused 41 poisoning incidents affecting 379 cattle in Queensland, Australia, between 1960 and 1984 (McKenzie and Dunster, 2008). *Bryophyllum* species may also be toxic to wildlife (McKenzie *et al*., 1987).

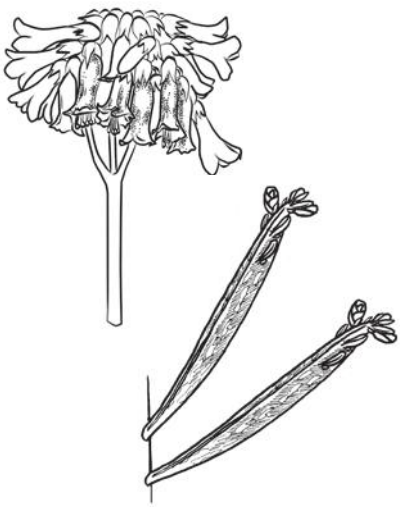


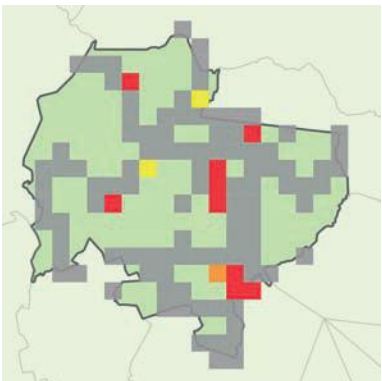
Bryophyllum daigremontianum (Raym.-Hamet & H. Perrier) Berger



Bryophyllum delagoense







STONECROP FAMILY
Crassulaceae

COMMON NAMES

English: mother-of-millions, finger plant, chandelier plant, pregnant plant

DESCRIPTION
Living for more than one year but less than two, erect, spineless, succulent herb (30–180 cm high), mostly unbranched, reproducing rapidly, mainly from plantlets (bulbils) which develop at the tip of the leaves; often forming dense stands.

Leaves: Pale green, with darker green to violet-brown and reddish spots or mottles; cylindrical in shape, somewhat elongated with almost parallel sides, narrow (15–150 mm long and 2–6 mm wide), with a small lengthwise groove; 2–9 small conical teeth at the end of each leaf which produce plantlets (bulbils) which drop to the ground and grow; leaves held opposite each other on young shoots but in whorls of three or alternate on older shoots.

Flowers: Pale orange to magenta red, tubular (2–4 cm long), occur in terminal clusters, drooping at the end of the stem.

Fruits: Follicles (dry fruits having one compartment that opens, along one side only, at maturity), papery and membranous (about 10 mm long) containing thousands of tiny egg-shaped seeds (0.6–2.5 mm long).

ORIGIN
Madagascar

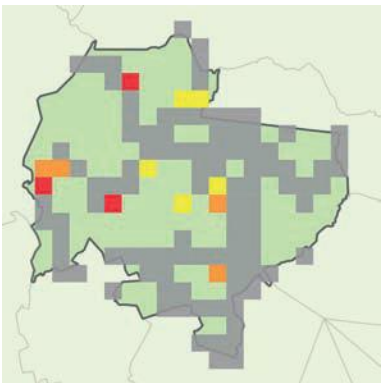
REASON FOR INTRODUCTION
Medicine and ornament

INVADES
Disturbed land, gardens, drainage ditches, woodlands, gullies, lowlands and savannah, especially rocky ridges and outcrops.

IMPACTS
An aggressive weed producing very large numbers of seeds and plantlets, this species forms dense monotypic stands, which displace native plant species. In Australia, it readily displaces grasses and legumes. It is toxic to livestock and humans and probably also to wildlife. Invasive *Bryophyllum* species, including *B. delagoense*, caused 41 recorded poisoning incidents affecting 379 cattle in Queensland, Australia, between 1960 and 1984 (McKenzie and Dunster, 2008). In 1997, 125 head of cattle died after eating this species on a travelling stock reserve near Moree in New South Wales, Australia (McKenzie *et al*., 1987). Symptoms of *B. delagoense* poisoning, which ultimately may result in death, include anorexia, depression, ruminal atony, diarrhoea, heart rate and rhythm abnormalities and dyspnoea (McKenzie and Dunster, 2008).

Bryophyllum delagoense (Eckl. & Zeyh.) Schinz

Bryophyllum fedtschenkoi



STONECROP FAMILY
Crassulaceae

COMMON NAMES

English: kalanchoe stonecrop, lavender-scallops

DESCRIPTION
Evergreen, succulent shrub, erect (up to 45 cm tall) to prostrate, often creeping and rooting, stems thin, branched, frequently light purple; reproducing rapidly, mainly from plantlets which develop at the end of the leaves.

Leaves: Bluish-green with a reddish tinge, egg-shaped or somewhat elongated (1–5 cm long and 0.5–2.5 wide), margins with blunt or rounded teeth; plantlets (bulbils) sometimes produced in the notches of leaf margins; leaves held opposite each other on the stem and evenly spaced, leaf stalk short.

Flowers: Brownish-pink flowers, tubular (2.5–3 cm long), pendulous.

Fruits: Follicles (dry fruits having one compartment that opens, along one side only, at maturity), papery and membranous containing thousands of tiny egg-shaped seeds (0.6 mm long).

ORIGIN
Madagascar

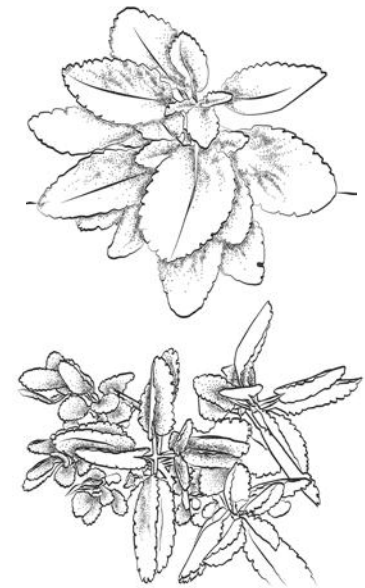
REASON FOR INTRODUCTION
Ornament

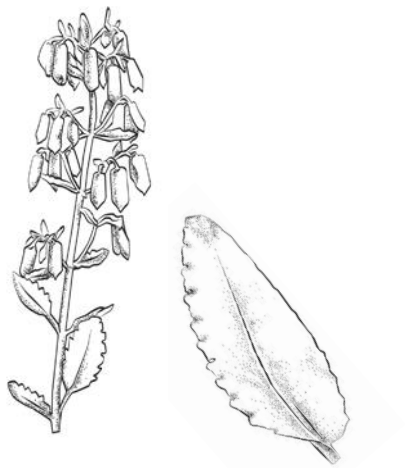
INVADES
Disturbed land, gardens, urban open space, drainage ditches, gullies and savannah, especially rocky ridges and outcrops.

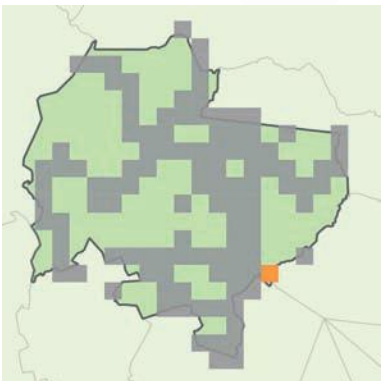
IMPACTS
Has the ability to form dense stands, displacing native plant species, especially in semi-arid areas where soil moisture is limited. Many impacts are considered to be similar to those of other *Bryophyllum* species.

Bryophyllum fedtschenkoi
(Raym.-Hamet & H. Perrier) Lauz.-March

Bryophyllum pinnatum







STONECROP FAMILY
Crassulaceae

COMMON NAMES

English: air plant, cathedral bells, green mother-of-millions, resurrection plant

DESCRIPTION
Evergreen, erect, and hairless with succulent and hairless stems (50–200 cm tall), nearly woody below, simple or little branched, with red stripes or spots.

Leaves: Green, streaked with purple, edged with orange-red; fleshy, simple or with 3–5-leaflets (leaves 5–25 cm long and 2–12.5 cm wide); plantlets (bulbils) produced in the notches of leaf margins; leaf stalks broader towards the base (2.5–10 cm long).

Flowers: Pale yellow to green with red to violet lines that become denser as the flowers mature, lantern-shaped (up to 7 cm long), pendulous or drooping.

Fruits: Follicles (dry fruits having one compartment that opens, along one side only, at maturity), papery and membranous (about 15 mm long), with four compartments, containing numerous minute brownish coloured seeds (about 0.8 mm long).

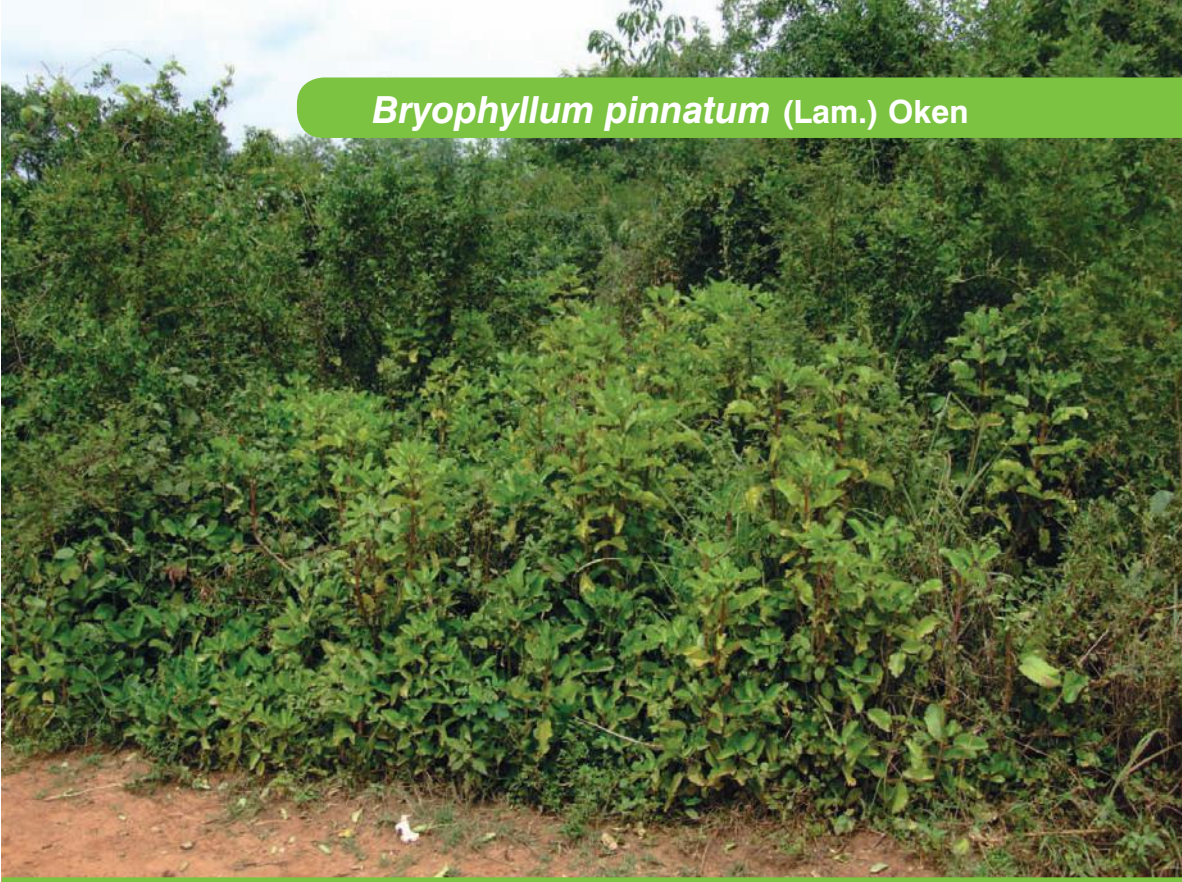
ORIGIN
Madagascar

REASON FOR INTRODUCTION
Medicine and ornament

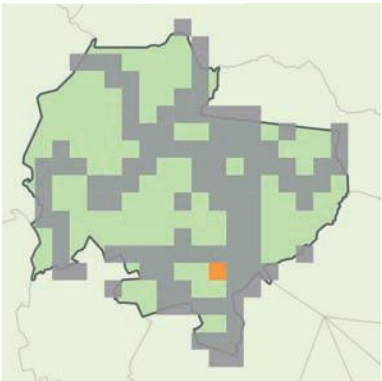
INVADES
Roadsides, disturbed land, wastelands, gardens, forests, forest edges/gaps, woodlands, woodland gaps/edges and forest gaps/edges.

IMPACTS
Readily establishes monospecific stands, to the detriment of native plant species. On Saint John, in the US Virgin Islands, large areas of herbaceous vegetation have been replaced by dense stands of *B. pinnatum* (Ting, 1989) and on the Galápagos Islands, thick carpets of *B. pinnatum* are preventing the regeneration of native plant species (Tye, 2001). The species is considered to be allelopathic, which may contribute to its invasion success, including its displacement of crops on the Galápagos Islands (Soria et al., 2002). *B. pinnatum* is one of the three most prevalent invasive plant species recorded in rural humid areas on inhabited islands of the Galápagos (Guezou *et al.*, 2010). Like other *Bryophyllum* species, it is also toxic. Two adult cattle died within 48 hours of being fed large amounts of *B. pinnatum* plants (Reppas, 2008). Symptoms included hyper-salivation, ataxia, severe cardiac arrhythmia and laboured respiration (Reppas, 2008). *B. pinnatum* is also an alternative host for crop pests.

Bryophyllum pinnatum (Lam.) Oken



Bryophyllum proliferum



STONECROP FAMILY
Crassulaceae

COMMON NAMES

English: blooming boxes, green mother of millions

DESCRIPTION
Evergreen succulent, erect (up to 3 m tall); almost woody stems are robust and four-angled (up to 5 cm in diameter).

Leaves: Green, fleshy, once-divided (up to 30 cm long), with 7–11 asymmetrical somewhat elongated, sword- to egg-shaped leaflets (7–15 cm long and 1.5–5 cm wide), margins often purple and blunt/rounded to tooth-like; leaf stalk is broadened near base (up to 16 cm long).

Flowers: Greenish-yellow with pinkish-red tips, bell-shaped, pendulous.

Fruits: Not seen in East Africa.

ORIGIN
Madagascar

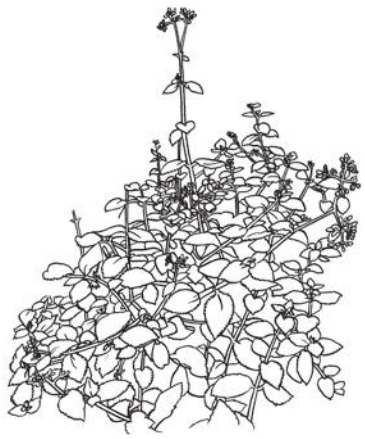
REASON FOR INTRODUCTION
Medicine and ornament

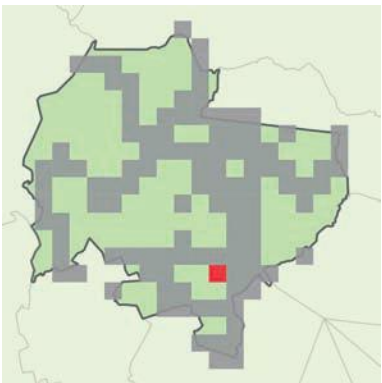
INVADES
Roadsides, disturbed land, gardens, forest gaps/edges and woodland gaps/edges.

IMPACTS
Forms dense stands which exclude plants of native species and the organisms associated with them. Readily establishes in forest edges and gaps in parts of Nairobi and has established in the field from some gardens in Laikipia. Many impacts are considered to be similar to those of other *Bryophyllum* species.

Bryophyllum proliferum Bowie ex Hook

Crassula sarmentosa





STONECROP FAMILY
Crassulaceae

COMMON NAMES

English: Jade-tree, showy trailing jade

DESCRIPTION
Evergreen, hairless, low-growing, creeping, succulent herb (40 cm tall) with stems to 80 cm long, rarely branched; young stems sometimes tinged with reddish-purple.

Leaves: Green to yellowish-green and occasionally with a reddish tinge on the leaf margins, rubbery, thick, egg- to oval- to sword-shaped [2-3.5 (-6) long and 1.5-2 (-3.5) cm wide], margins have small teeth, leaves held opposite each other on stems; leaf stalks to 3 mm long.

Flowers: Pinkish white, star-shaped, petals (brightly coloured part of flower) (3.5-5 mm long and 1 mm wide), held in dense and branched terminal clusters.

Fruits: Follicles (dry fruits having one compartment that opens, along one side only, at maturity) slightly recurved, smooth.

ORIGIN
South Africa

REASON FOR INTRODUCTION
Ornament

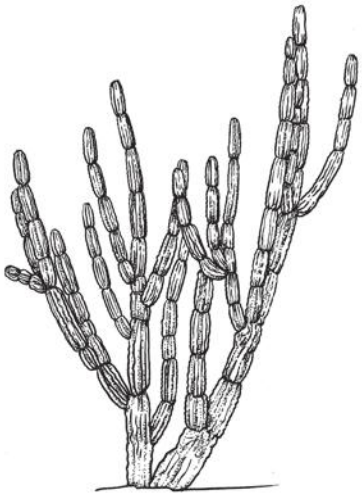
INVADES
Roadsides, disturbed areas, plantations, forest understorey, forest gaps/edges, woodland understorey and woodland gaps/edges wherever there is sufficient shade.

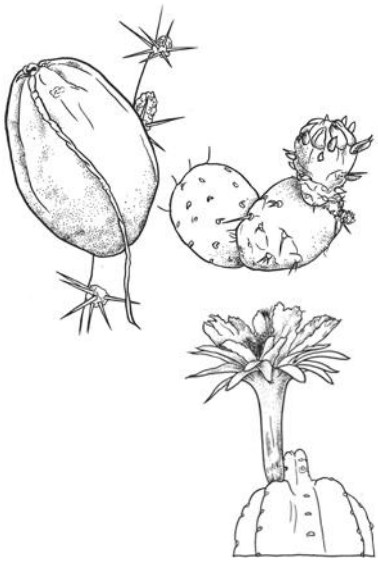
IMPACTS
C. sarmentosa is a fast grower that can form thick mats below trees, displacing other plant species. Little is known about the impacts of this plant, although casual observation suggests that it has the ability to smother plants of other species. In Zimbabwe it is naturalized on roadsides and on disturbed ground, "often near gardens" (Flora of Zimbabwe, 2016). In New South Wales, Australia, it is naturalized on "sandy soils in sclerophyll forest of *Eucalyptus maculata* Hook. f. (Myrtaceae), *E. paniculata* Sm. and *E. longifolia* Link (Toelken, 1981).

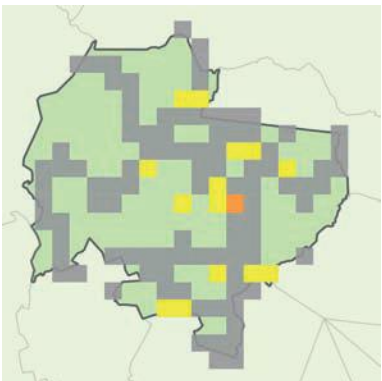
Notes: It has escaped from cultivation in Laikipia County and in parts of Nairobi, Kenya, forming dense mats in plantation and woodland understoreys. Likely to be far more widespread than surveys suggest.

Crassula sarmentosa Thunb.

Cereus jamacaru







CACTUS FAMILY
Cactaceae

COMMON NAMES

English: queen of the night, Peruvian apple cactus, pitaya

DESCRIPTION
Evergreen, spiny, cactus tree [3–10 (–18) m high]; branched irregularly, with thick cylindrical succulent stems covered with spines growing in groups of 5–10, arising from a short, woody trunk; branches are grey-green to blue with (3)–6–(8) prominent ribs.

Leaves: None

Flowers: Showy white with red tips (15 cm long and 7–10 cm across), flowering at night; flowers of *Cereus repandus* (L.) Mill. [syn.: *Cereus peruvianus* (L.) Mill.] are only about 8 cm long.

Fruits: Berries (fleshy fruits that don't open at maturity), green turning red or pink as they mature, smooth with no spines (6–10 cm long and 4–8 cm wide); white pulp with black seeds.

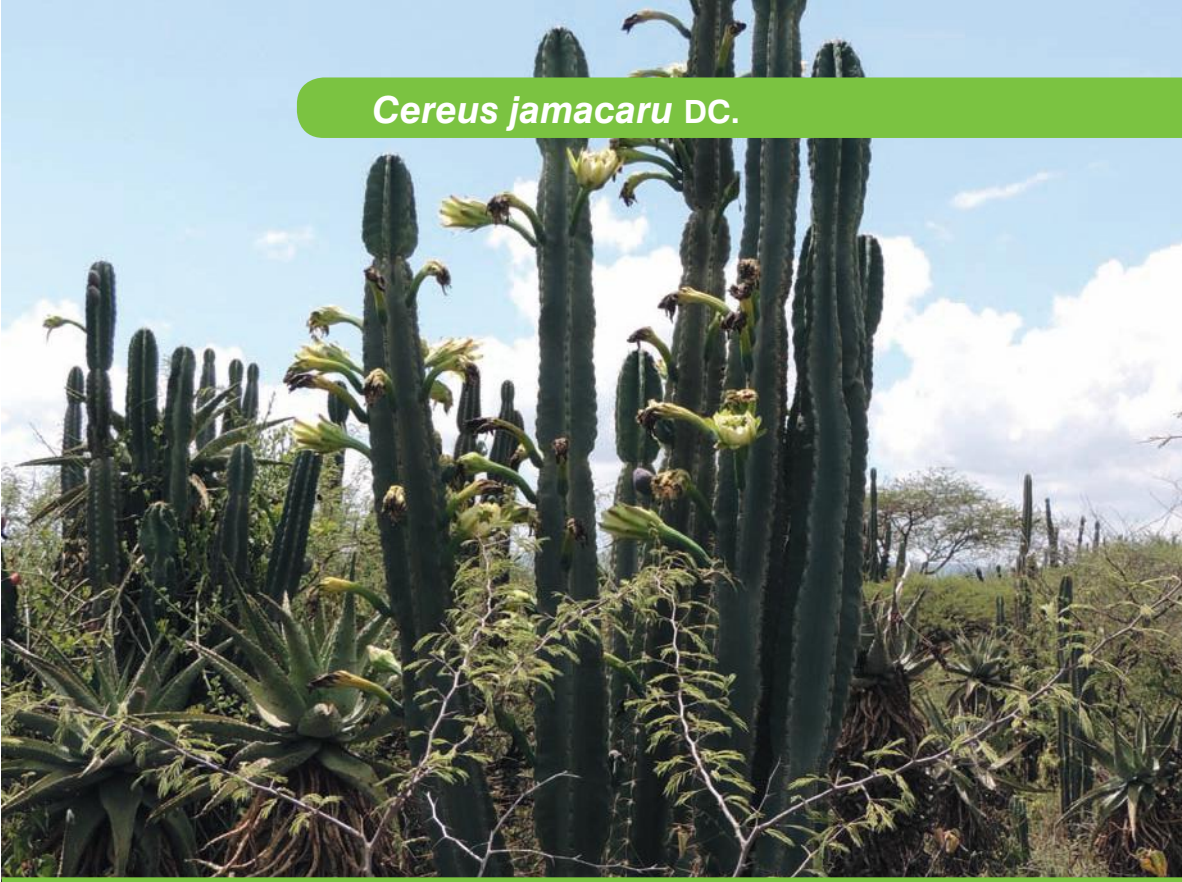
ORIGIN
North-east Brazil

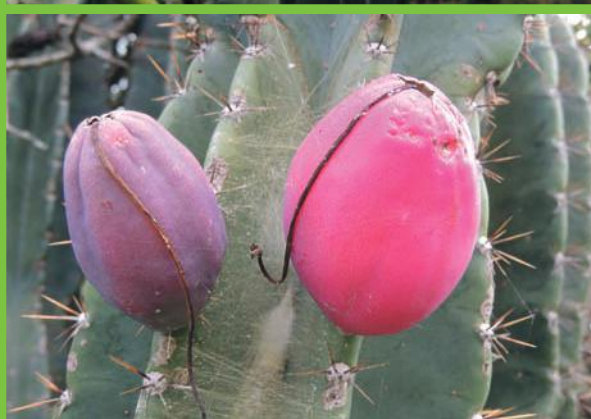
REASON FOR INTRODUCTION
Edible fruit, hedge/barrier and ornament.

INVADES
Woodland gaps/edges, savannah and rocky outcrops.

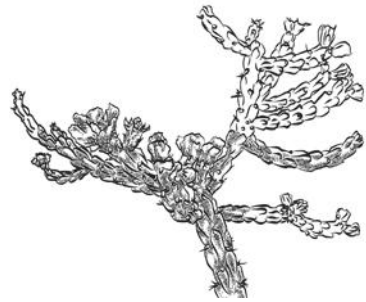
IMPACTS
Can form dense stands, displacing native plants and preventing access to forage by grazers and browsers, resulting in reduced livestock and/or wildlife carrying capacities. Thickets may impede the movement of livestock and wild herbivores, while the spines may cause injuries to people as well as to animals. Large stands growing under trees may prevent access to shade by livestock, contributing to heat stress. Additional impacts are similar to those recorded for other invasive cactus species.

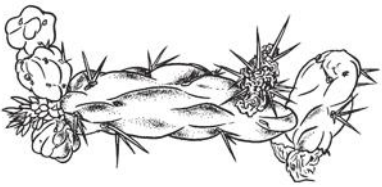
Cereus jamacaru DC.

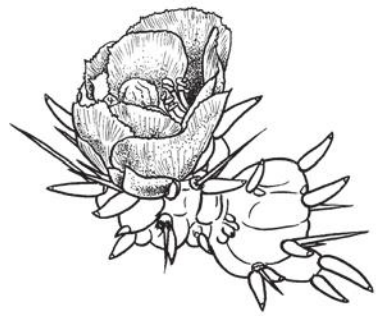


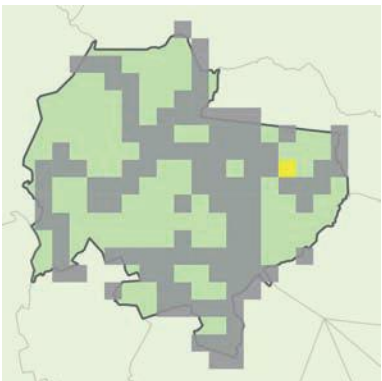


Cylindropuntia imbricata









CACTUS FAMILY
Cactaceae

COMMON NAMES

English: cane cactus, chain-link cactus, devil's rope pear, imbricate prickly pear, tree cholla.

DESCRIPTION
Succulent spiny, much-branched shrub (2–4 m tall), erect trunk with dull grey-green stems made up of a number of cylindrical segments (30–40 cm long and 3–5 cm thick) covered in small humps that give them a woven rope-like appearance; armed with white spines (2–3 cm long) which are initially covered with loose, silver-grey to yellow, papery sheaths, old branches hang downwards.

Leaves: Reduced, cylindrical or cone-shaped (1–2 cm long), shed early.

Flowers: Purple-pink or reddish-purple (up to 6 cm long and 3–9 cm across), found at the tips of segments, showy.

Fruits: Berries (fleshy fruits that don't open at maturity), green turning yellow-green as they mature, egg-shaped with the narrower end at the base spineless (25–70 mm long and 20–40 mm wide); seeds yellow-brown, mostly sterile.

ORIGIN
Mexico and southern USA.

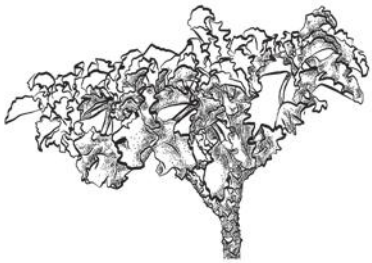
REASON FOR INTRODUCTION
Hedge/barrier and ornament.

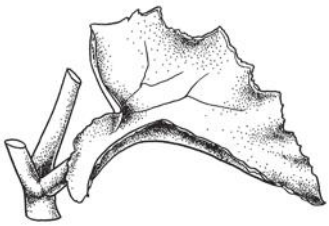
INVADES
Disturbed land, woodland edges/gaps, savannah, grassland and gullies.

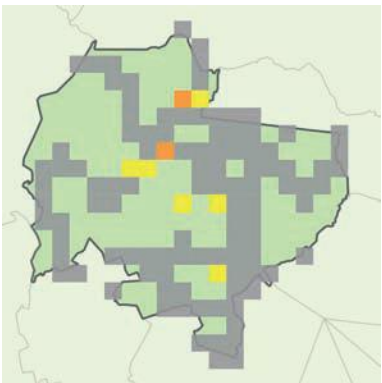
IMPACTS
Rope pear forms dense thickets which displace native species and inhibit the movement of people, livestock and wildlife. At lower densities, infestations prevent livestock and wildlife from gaining access to forage species growing under its canopy, and so reduce the livestock carrying capacities of pastures. The plant is also very spiny, and may cause injuries to humans and to animals. Additional impacts are assumed to be similar to those recorded for other invasive cactus species.

Cylindropuntia imbricata (Haw.) Knuth

Kalanchoe beharensis







STONECROP FAMILY
Crassulaceae

COMMON NAMES

English: elephant's ear kalanchoe, felt bush, velvet bush, velvet elephant ear, velvet leaf

DESCRIPTION
Succulent shrub or small tree (to 3 m tall), stem is slender (2–12 cm diameter), succulent, becoming hard and woody with age with conspicuous leaf scars with sharp projections on either side, covered in brownish hairs.

Leaves: Olive green to dark green, hairless to completely covered with dense felt-like glandular hairs with mature leaves having a rusty colour on top and silvery underneath; fleshy, triangular (7–40 cm long and 8–30 cm wide), irregularly lobed and crimped at the edges, held opposite each other on stems and crowded at the tips of branches.

Flowers: Red-orange or yellowish in terminal inflorescences (50–60 cm high).

Fruits: Papery and membranous containing thousands of tiny seeds.

ORIGIN
Madagascar

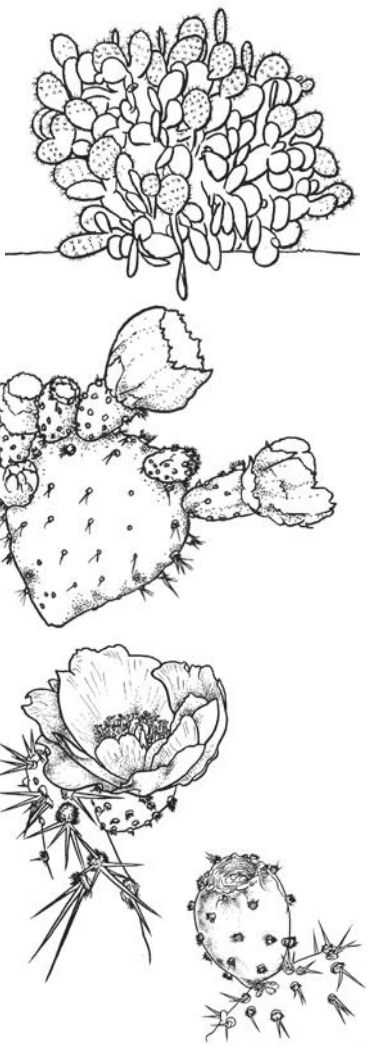
REASON FOR INTRODUCTION
Ornament

INVADES
Disturbed areas, gardens and rocky outcrops in savannah.

IMPACTS
Naturalizes rapidly and forms dense stands that exclude native plant species and associated organisms.

Kalanchoe beharensis Drake

Opuntia elatior



CACTUS FAMILY
Cactaceae

COMMON NAMES

English: prickly pear

DESCRIPTION
Succulent shrub, forming dense branched clumps (to 5 m high); modified stems called cladodes are olive-green and egg-shaped to nearly round to somewhat elongated with almost parallel sides (30–40 cm long); areoles (raised structures or bumps on the stems of cacti, out of which grow clusters of spines) 2–4 cm apart with 2–8 spines each, which are needle-like and dark brown (2–7 cm long).

Leaves: Green with reddish tips, tiny (up to 4 mm long).

Flowers: Yellow with reddish or red stripes (up to 5 cm across).

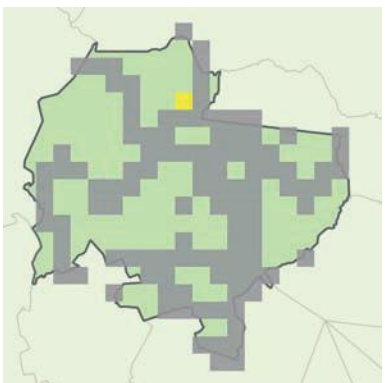
Fruits: Berries (fleshy fruits that don't open at maturity), green turning reddish as they mature, egg-shaped.

ORIGIN
Costa Rica, Panama, Venezuela, Columbia and the Caribbean.

REASON FOR INTRODUCTION
Edible fruit, hedge/barrier and ornament.

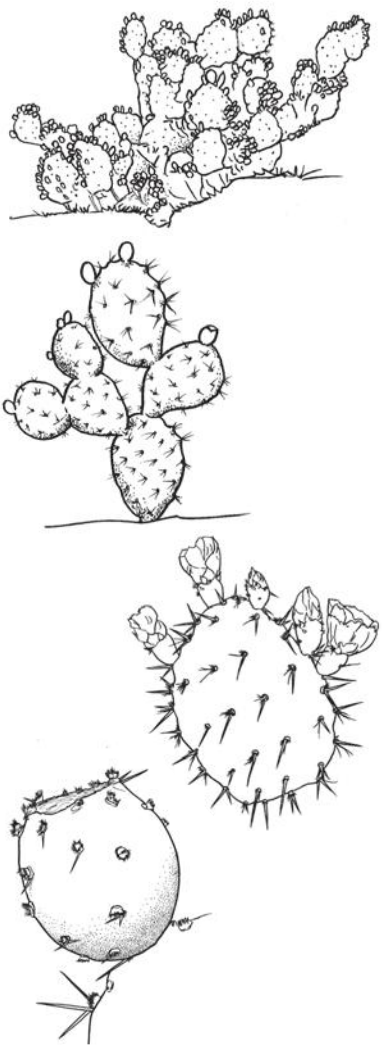
INVADES
Roadsides, disturbed areas, savannah, rocky outcrops, lowlands and gullies.

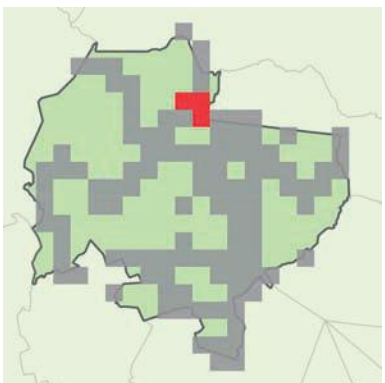
IMPACTS
Forms dense, impenetrable thickets, reducing access to available forage and to other natural resources such as water. Communities around Lake Baringo, Kenya, have lost valuable grazing land and claim the thickets harbour dangerous animals. The spines also cause injuries to people, livestock and wild animals. Consumption of the fruit by livestock may result in impacts of the kind recorded for *O. stricta* (page 120). Additional impacts are assumed to be similar to those recorded for other invasive cactus species.



Opuntia elatior Miller

Opuntia engelmannii





CACTUS FAMILY
Cactaceae

COMMON NAMES

English: cows' tongue cactus, desert prickly pear, Engelman's prickly pear.

DESCRIPTION
Succulent erect shrub, with many ascending to sprawling branches, forming dense clumps [1–3 (–3.5) m high]; modified stems called cladodes are yellow-green to blue-green, flattened, circular or broadly egg-shaped to diamond-shaped, or tapering at the end (15–40 cm long and 10–40 cm wide); 5–8 oval areoles (raised structures or bumps on the stems of cacti, out of which grow clusters of spines) in a row diagonally across the centre of the cladode, 2.5–4 cm apart; (0)–1–6–(12) spines per areole, spines [1–4 (–5) cm long], white to yellow, red to dark brown at the base.

Leaves: Green, reduced (3–9 mm long) and shed early.

Flowers: Orange-yellow or orange, rarely pink to red or whitish (30–40 mm long).

Fruits: Berries (fleshy fruits that don't open at maturity), green turning purple or dark red throughout as they mature, egg-shaped with narrower end at base (3.5–9 cm long and 2–4 cm wide), almost spineless.

ORIGIN
Southern and Central USA to Mexico.

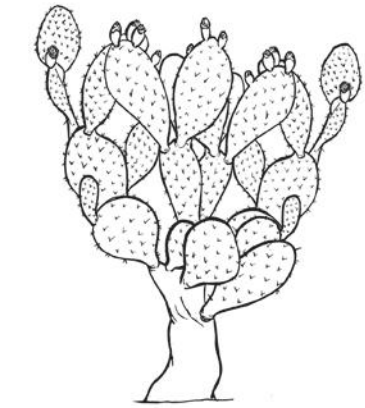
REASON FOR INTRODUCTION
Edible fruit, hedge/barrier and ornament.

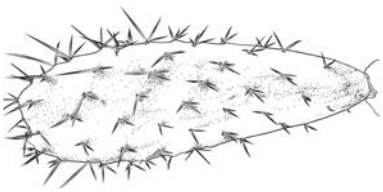
INVADES
Roadsides, disturbed land, savannah, rocky outcrops especially in semi-arid areas.

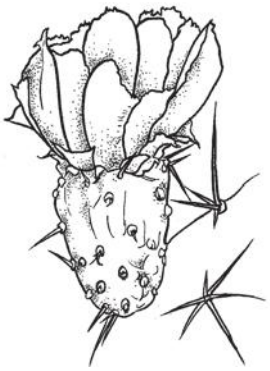
IMPACTS
Forms dense thickets wherever it establishes, displacing native plant and animal species. Grasses and other forage species growing around the plants are not consumed because the cactus spines pose a hazard to livestock and wild animals. Large infestations significantly reduce livestock carrying capacities and deprive wildlife of habitat. Stands also inhibit or prevent the free movement by people, livestock and wild animals. Consumption of the fruit by livestock may result in impacts of the kind recorded for *O. stricta*. Additional impacts are assumed to be similar to those recorded for other invasive cactus species.

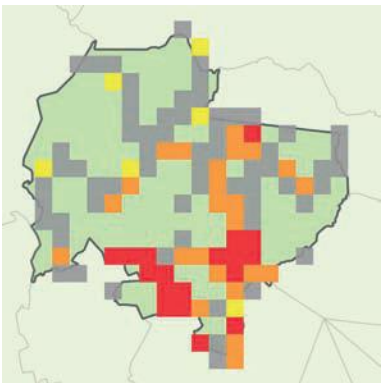
Opuntia engelmannii Salm-Dyck ex Engelmann

Opuntia ficus-indica









CACTUS FAMILY
Cactaceae

COMMON NAMES

English: cactus pear, Indian fig, mission prickly pear, prickly pear, sweet prickly pear.
Swahili: mpungate

DESCRIPTION
Succulent large shrub or small tree [1.5–3 (–7) m high], forming a trunk with age; modified stems called cladodes are dull green or blue-green, flattened, much longer (20–60 cm) than broad (10–20 cm); spines (up to 2.5 cm long) are white or off-white, variable, absent or 1–2 or more per areole (raised structures or bumps on the stems of cacti, out of which grow clusters of spines).

Leaves: Minute and shed early.

Flowers: Orange or yellow, showy (2–3 cm wide).

Fruits: Berries (fleshy fruits that don't open at maturity), green turning yellow, orange, red or purple as they mature, succulent, oval (5–10 cm long and 4–9 cm wide) with pale pulp.

ORIGIN
Mexico.

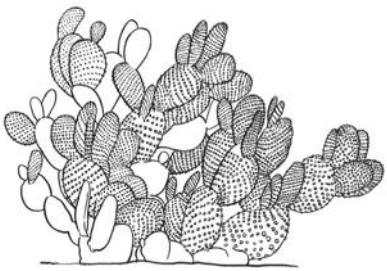
REASON FOR INTRODUCTION
Edible fruits, fodder, hedge/barrier and ornament.

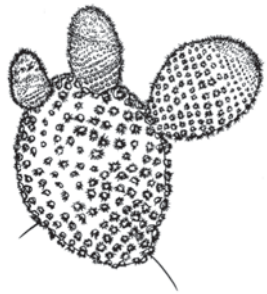
INVADES
Roadsides, disturbed land, savannah, dry and rocky places in arid and semi-arid regions.

IMPACTS
Readily establishes large stands, displacing native plant and animal species. A reduction in available forage for livestock resulted in the abandonment of many farms in South Africa early in the 20th century. Beinart (2003) gives an example of a farmer in the Karoo, South Africa, who 'lost control of prickly pear on his farm and was forced to sell' because the prickly pear infestations had become so dense that his livestock could no longer be herded and his sheep were dying. The glochids (barbed hairs or bristles) on the fruit cause swellings and sores extending down the gullet to the internal linings of the digestive system, diminishing an animal's capacity to eat, and sometimes resulting in death (Beinart, 2003). The claim was made in 1893 that prickly pear was spreading so fast in South Africa that half the farming population in the Cape would be reduced to poverty if nothing were done. Additional impacts are assumed to be similar to those recorded for other invasive cactus species.

Opuntia ficus-indica (L.) Mill.

Opuntia microdasys





CACTUS FAMILY
Cactaceae

COMMON NAMES

English: angel's wings, bunny-ear prickly pear, teddy bear cactus

DESCRIPTION
Succulent evergreen shrub, forming thickets (0.4–0.6 m or more high); modified stems called cladodes are green, velvety, somewhat elongated with almost parallel sides, egg-shaped or almost round (6–15 cm long and 6–12 cm wide); 8–13 (–16) areoles (raised structures or bumps on the stems of cacti, out of which grow clusters of spines) prominent per diagonal row across midstem section; no spines but many glochidea (barbed hairs or bristles), yellow to reddish brown.

Leaves: None

Flowers: Yellow turning apricot to orange with age with outer petals often tinged red (4 cm long and 4 cm wide).

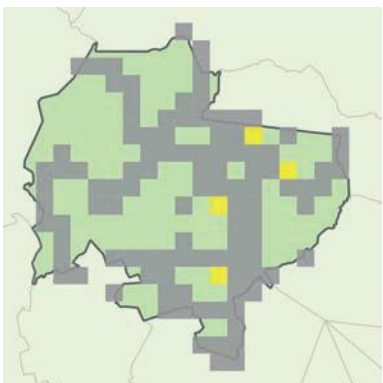
Fruits: Berry (fleshy fruits that don't open at maturity), green turning red-purple as they mature, almost round (3 cm in diameter), with black oval seeds.

ORIGIN
Northern Mexico

REASON FOR INTRODUCTION
Hedge/barrier and ornament

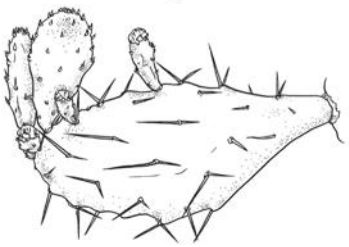
INVADES
Roadsides, disturbed land and savannah in semi-arid areas.

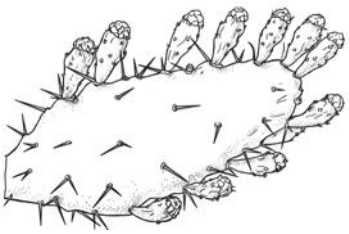
IMPACTS
Rapidly establishes large and dense infestations, to the detriment of native plant species. Large infestations reduce livestock carrying capacities and prevent access to water and other resources. Infestations also inhibit the movement of people, livestock and wildlife. Additional impacts are assumed to be similar to those recorded for other invasive cactus species.

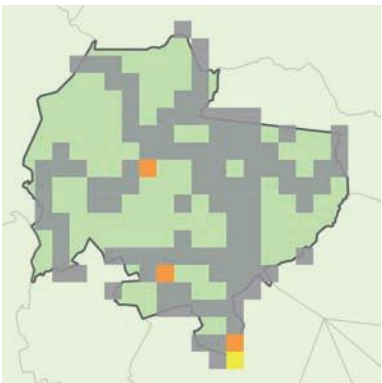


Opuntia microdasys (Lehm.) Pfeiff.

Opuntia monacantha







CACTUS FAMILY
Cactaceae

COMMON NAMES

English: Barbary fig, cochineal prickly pear, common prickly pear, drooping prickly pear.

DESCRIPTION
Succulent shrub or small tree [2–3 (–6) m tall], sometimes with a short trunk, usually with a large, much-branched top and drooping upper segments; modified stems called cladodes are bright green and shiny especially when young, flattened, usually thin, egg-shaped to somewhat elongated with almost parallel sides [10–30 cm long and 7.5–10 (–12.5) cm wide], tapered towards the base; 1–2 (–3) spines per areole (raised structures or bumps on the stems of cacti, out of which grow clusters of spines) with numerous spines (2–4 cm) on the trunks.

Leaves: Green, minute (2–3 mm long), cone-shaped, shed early.

Flowers: Yellow or orange-yellow with the outer petals tinged red (5–7.5 cm long and 7.5–10 cm wide).

Fruits: Berries (fleshy fruit that don't open at maturity), green turning light green to yellow with red-purple shades as they mature, egg- to pear-shaped (about 6 cm long and 4–5 cm wide).

ORIGIN
Argentina, Brazil, Paraguay and Uruguay.

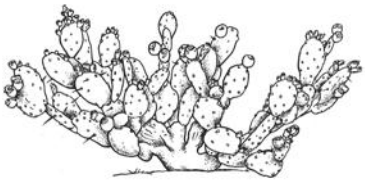
REASON FOR INTRODUCTION
Edible fruits, fodder, hedge/barrier and ornament.

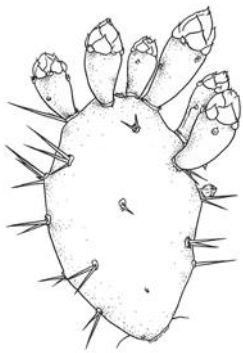
INVADES
Roadsides, disturbed land, forest edges/gaps, woodland edges/gaps, savannah and coastal bush.

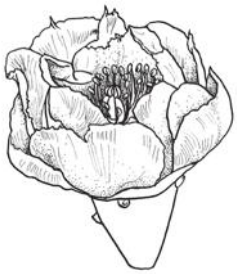
IMPACTS
Forms dense, impenetrable thickets, displacing native plant species. Infestations also inhibit access to natural resources such as grazing and water. Expansive stands reduce livestock carrying capacities. Pastoralists in Kenya claim that dense stands provide cover for dangerous animals, posing an added threat to livestock. Additional impacts are assumed to be similar to those recorded for other invasive cactus species.

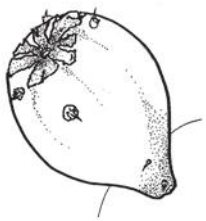
Opuntia monacantha Haw.

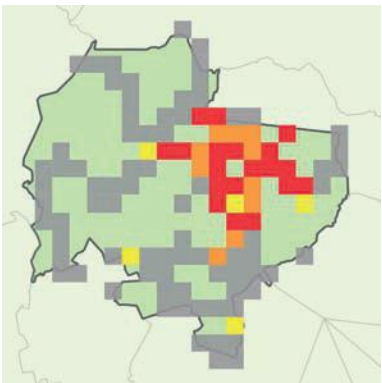
Opuntia stricta











CACTUS FAMILY
Cactaceae

COMMON NAMES

English: Australian pest pear, common pest pear, erect prickly pear, sour prickly pear.

DESCRIPTION
Succulent erect, spreading shrub, [0.5–1.3 (–2) m high]; thicket-forming; modified stems called cladodes are blue-green, longer than broad (10–20 cm long and 7.5–14 cm wide); 3–5 areoles (raised structures or bumps on the stems of cacti, out of which grow clusters of spines) per diagonal row on each cladode; 1–2 straight and flattened yellow spines (1.5–4 cm long) usually restricted to marginal areoles as opposed to *O. stricta* (Ahw.) Haw. var. *dillenii* (Ker Gawl.) Benson where there are 4–7 (–11) banded spines (1.5–4 cm long) on most areoles.

Leaves: Cylindrical, minute and shed early.

Flowers: Yellow and large (5–6 cm long and 5–6 cm wide).

Fruits: Berries (fleshy fruits that don't open at maturity), green turning red-purple as they mature, egg-shaped (4–6 cm long and 2.5–3 cm wide), outer surface smooth with clusters of glochids (barbed hairs or bristles), narrowed at the base, purple sour pulp, white seeds.

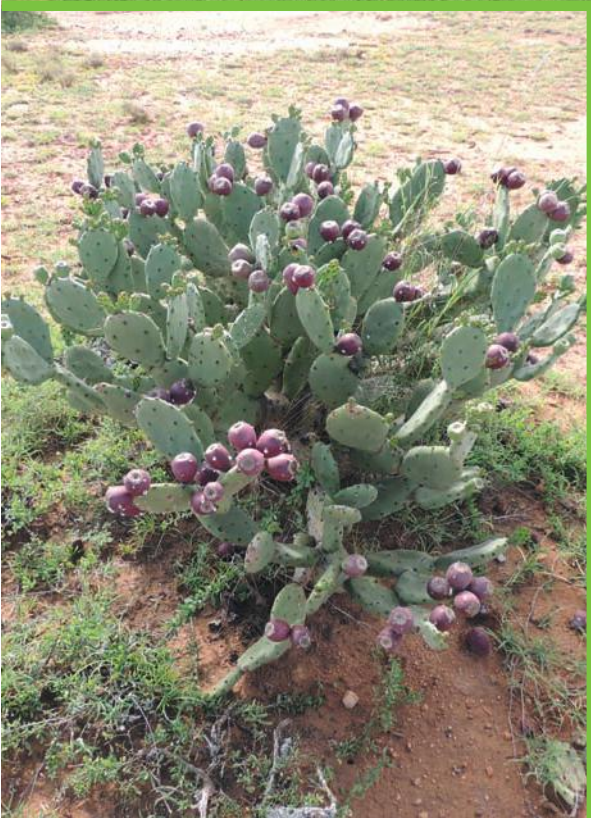
ORIGIN
Southeastern USA, Mexico and the Caribbean.

REASON FOR INTRODUCTION
Hedge/barrier and ornament.

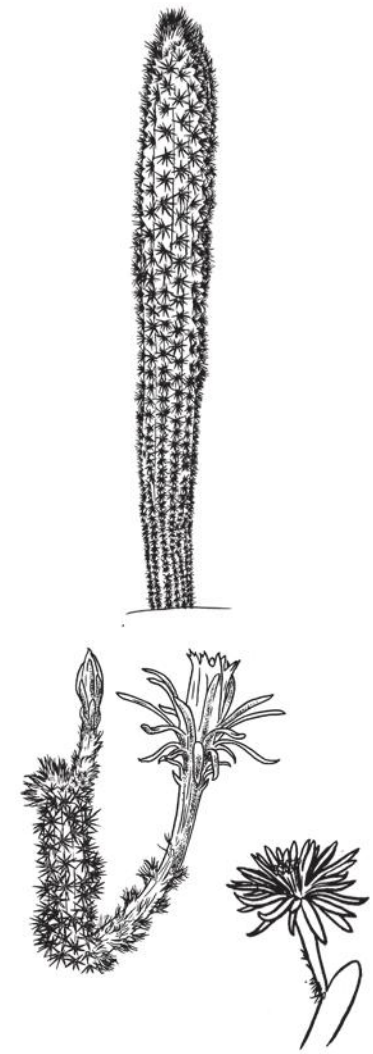
INVADES
Roadsides, wastelands, disturbed areas, rocky outcrops, savannah, grassland and riverbanks in arid to semi-arid regions.

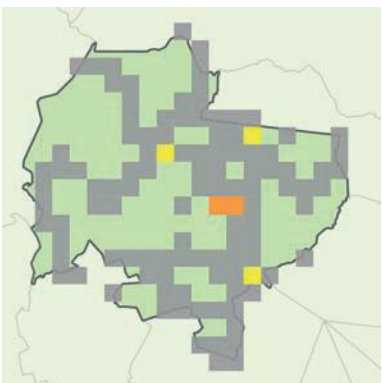
IMPACTS
Can form dense stands, preventing access to homes, water resources and pasture. On Madagascar, *O. stricta* has invaded land used for crop and pasture production, and has encroached on villages and roads, impeding human mobility (Larsson, 2004). Here, the cactus has had a negative impact on native grasses and herbs, and it is even affecting trees by inhibiting their growth and regeneration (Larsson, 2004). The small spines (known as glochids) on the fruit, when consumed by livestock, lodge in their gums, on their tongues or in their gastrointestinal tracts, causing bacterial infections, while the hard seeds may cause rumen impaction, which can be fatal, and which often leads to excessive, enforced culling of affected animals (Ueckert *et al*., 1990). People who consume the fruits develop diarrhoea and may suffer from serious infections caused by the spines (Larsson, 2004). In Kenya, *O. stricta* infestations have resulted in the abandonment of farmlands.

Opuntia stricta



Peniocereus serpentinus





CACTUS FAMILY
Cactaceae

COMMON NAMES

English: Mexican night-blooming cereus, serpent cactus, snake cactus

DESCRIPTION
Succulent, green stems erect or arching (up to 2 m tall), branching from base (3–5 cm in diameter), with 10–12 (–17) ribs, areoles (raised structures or bumps on the stems of cacti, out of which grow clusters of spines) 1 cm apart; spines soft, 10–14 per group, unequal, white to brown but red or purplish when young.

Leaves: None

Flowers: White, tinged red outside, [(12–) 15–20 (–25) cm long and 8–10 (–15cm) wide], flowering at night.

Fruits: Berries (fleshy fruits that don't open at maturity), red, egg-shaped to round (up to 4 cm long), many areoles with whitish hairs.

ORIGIN
Mexico

REASON FOR INTRODUCTION
Hedge/barrier and ornament.

INVADES
Roadsides, disturbed areas and overgrazed land.

IMPACTS
Forms dense stands which displace native plant and animal species. Currently not very abundant in Kenya, but should this species become widespread, impacts may be similar to those of other invasive cactus species.

Peniocereus serpentinus (Lag. & Rodr.) N.P. Taylor

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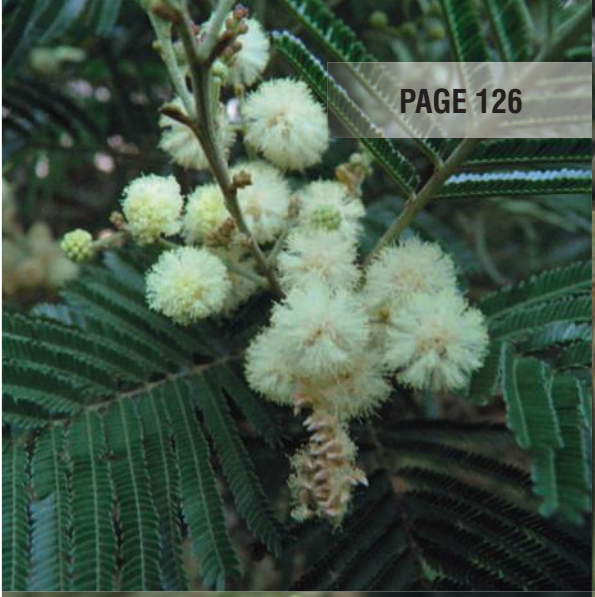
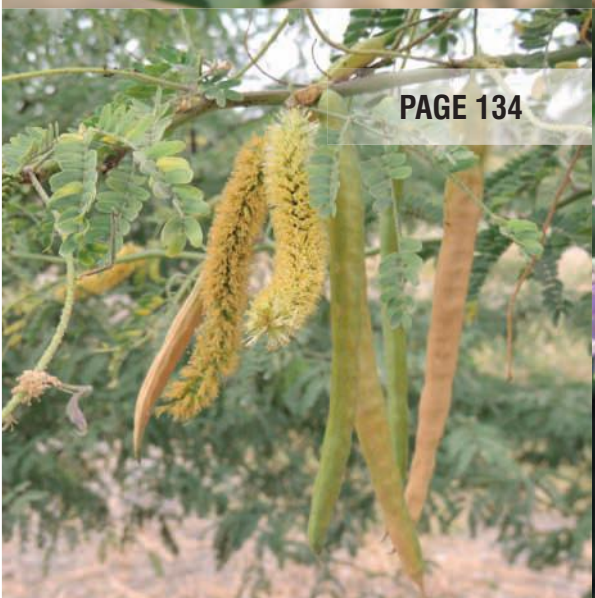
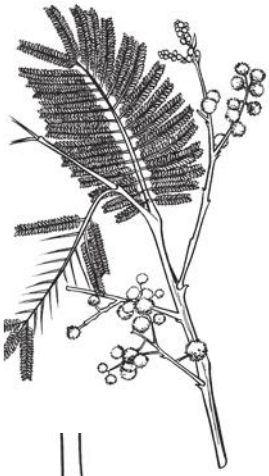
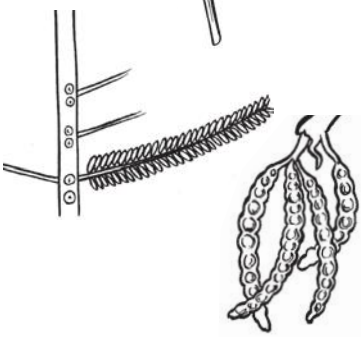


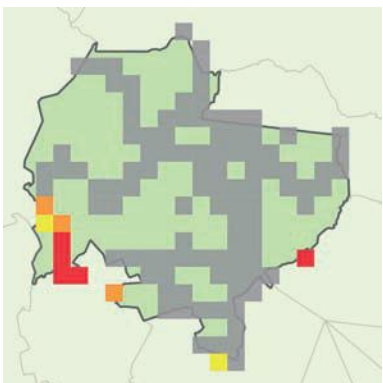


TREES

Acacia mearnsii







PEA FAMILY
Fabaceae; Subfamily: Mimosaceae

COMMON NAMES
English: Australian acacias, black wattle, tan wattle.
Kikuyu: muthanduku; Swahili: muwati; Chagga: man'goi
Kisii: omotandege; Kamba: munyoonyoo

DESCRIPTION
Evergreen tree [5–10 (–20) m high], with no thorns/spines, round or shapeless all parts finely hairy with growth tips golden-hairy.

Bark: Smooth green-grey, later black and grooved, producing a brown resinous gum.

Leaves: Dark olive-green, twice-divided (8-12 cm long), 9–20 pairs of leaf branchlets, each with 20–60 pairs of leaflets (1.5–4.0 mm long); raised glands occur at and between the junctions of leaflet stalks along the whole midvein; leaves positioned alternately on stem.

Flowers: Pale yellow or cream in colour, in round flowerheads (5 mm across), fragrant.

Fruits: Pods (several-seeded dry fruits that split open at maturity), green turning brown as they mature, straight or twisted (6–15 cm long and 5–9 mm wide), usually constricted between seeds, and finely hairy.

ORIGIN
Southeast Australia and Tasmania.

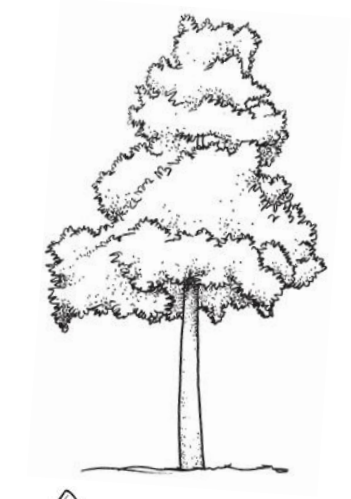
REASON FOR INTRODUCTION
Fuelwood, building materials, shelter, ornamental, erosion control and tanning.

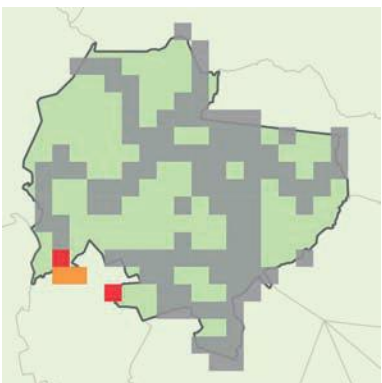
INVADES
Roadsides, disturbed land, wasteland, plantations edges/gaps, drainage ditches, forest edges/gaps, woodland edges/gaps, grassland, water courses, lowlands and gullies.

IMPACTS
Forms thickets which displace native vegetation and reduce biodiversity. By shading out plants of native species, and by shedding large quantities of litter, black wattle reduces floral diversity (Weber, 2003). By fixing nitrogen, the species alters nutrient cycling, making soils unsuitable for native plants of many species. In South Africa, costs associated with black wattle infestations include reduced stream flows, a heightened fire risk, increased erosion, destabilization of riverbanks, loss of grazing, nitrogen pollution, impairment of recreational activities, and diminished aesthetic appeal (de Wit, 2001). Losses in water runoff in South Africa, attributed to infestations of *A. mearnsii*, amount to an estimated 577 million m^3 of water annually (Versfeld *et al.*, 1998). Black wattle is also extremely invasive in India, having invaded shola forests and associated grasslands.

Acacia mearnsii De Wild

Acacia melanoxylon





PEA FAMILY
Fabaceae; Sub-family: Mimosaceae

COMMON NAMES

English: Australian blackwood, blackwood, hickory, Tasmanian blackwood

Kikuyu: kanuga

DESCRIPTION
Evergreen tree [8–15 (–35) m high] with no thorns/spines, tall, conical or pyramidal with a straight trunk (0.5 m in diameter) and a dense crown.

Bark: Dark greyish to black and deeply fissured.

Leaves: Dark green to greyish green, twice-divided on young plants and coppicing shoots; mature leaves are expanded leaf-stalks known as phyllodes which are almost erect, straight to slightly curved, somewhat elongated (4–16 cm long and 6–30 mm wide) with 3–5 prominent longitudinal veins and fine net-veins between; leaves held alternately on stem.

Flowers: Pale yellow, cream or whitish coloured globular/round flowerheads (5–10 mm across).

Fruits: Pods (several-seeded dry fruits that split open at maturity), green turning reddish-brown as they mature, flattened and twisted or coiled (4–15 cm long and 3.5–8 mm long); seeds almost encircled by pinkish-red/orange fleshy structure.

ORIGIN
Southeastern and eastern Australia and Tasmania.

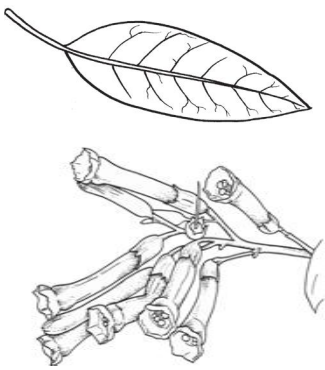
REASON FOR INTRODUCTION
Fuelwood, building materials, timber, shelter, ornament and erosion control.

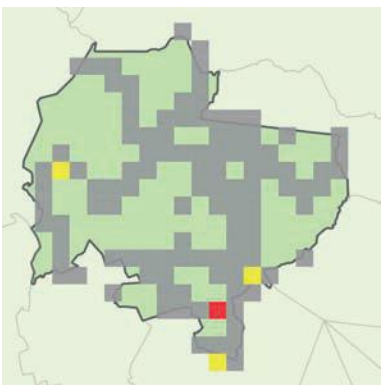
INVADES
Roadsides, disturbed areas, plantations, drainage ditches, forest edges/gaps, grasslands, riparian areas and lowlands.

IMPACTS
Forms dense thickets where it out-competes native plant species for water and light. Increases soil nitrogen levels, altering soil nutrient cycling. Uses copious amounts of water, significantly more water than the native vegetation it replaces, changing soil moisture conditions (Rutherford *et al*., 1986). Is the cause of allergenic contact dermatitis and asthma in people who work with the wood. Other impacts are similar to those of *Acacia mearnsii*.

Acacia melanoxylon R. Br.

Nicotiana glauca





TOMATO FAMILY
Solanaceae

COMMON NAMES

English: mustard tree, tobacco bush, tree tobacco, wild tobacco.

DESCRIPTION
Evergreen, hairless soft-wooded shrub or small tree (2–8 m tall); blue-green with purplish tints.

Leaves: Bluish or greyish-green, leathery and thick, sword-shaped or oval (5–25 cm long and 12 cm wide) with pointed tips, alternate, long stalks, leaves larger on young growth.

Flowers: Greenish-yellow, tubular (3–4 cm long), in terminal drooping clusters.

Fruits: Capsule (dry fruit that opens at maturity), green turning brown-black as they mature, egg-shaped, four-valved (15 mm long) containing tiny seeds.

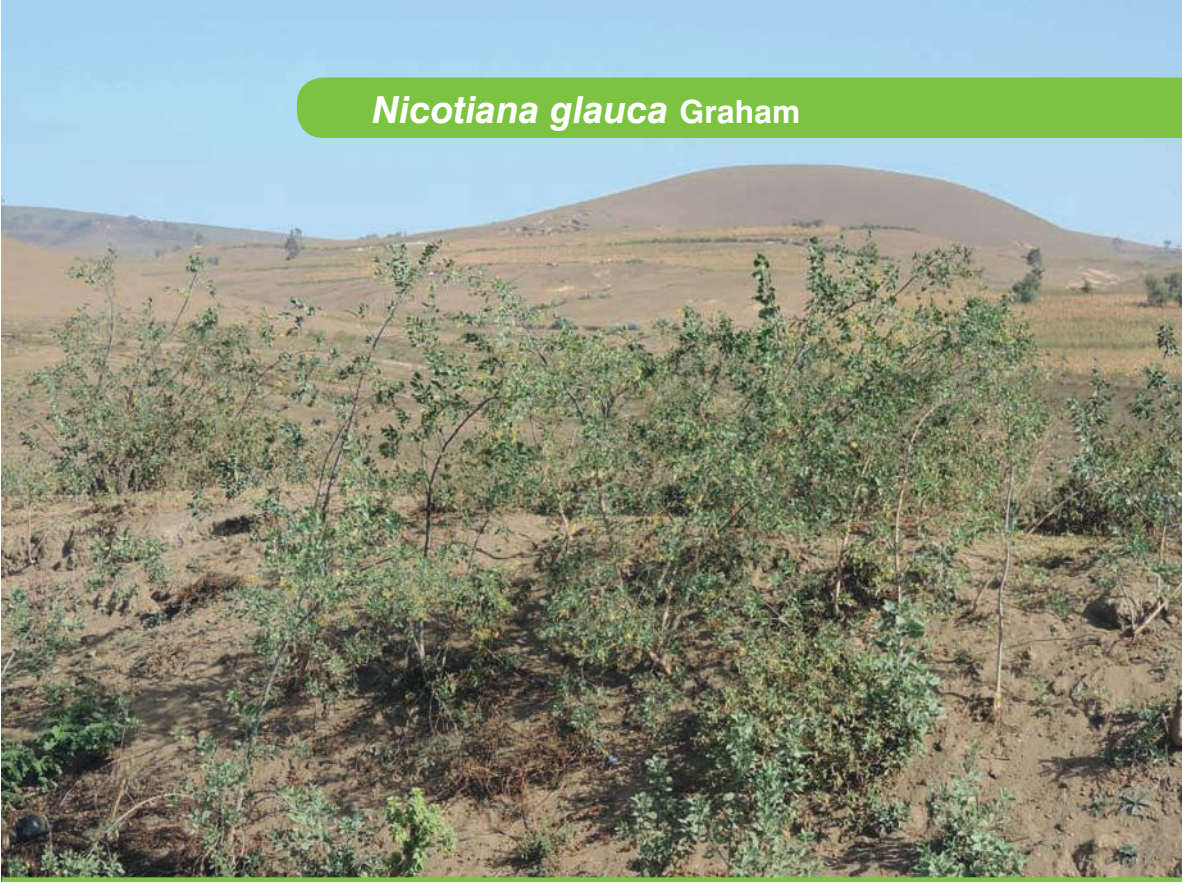
ORIGIN
Argentina, Brazil, Bolivia, Ecuador, Peru, Chile, Paraguay and Uruguay.

REASON FOR INTRODUCTION
Ornament.

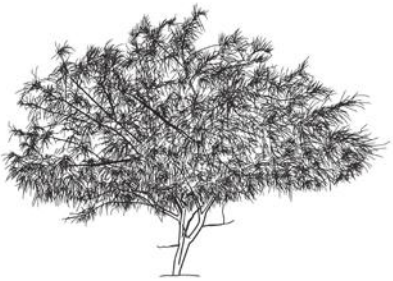
INVADES
Roadsides, wasteland, disturbed land, drainage ditches, floodplains, riverbanks, riverbeds and dry water channels.

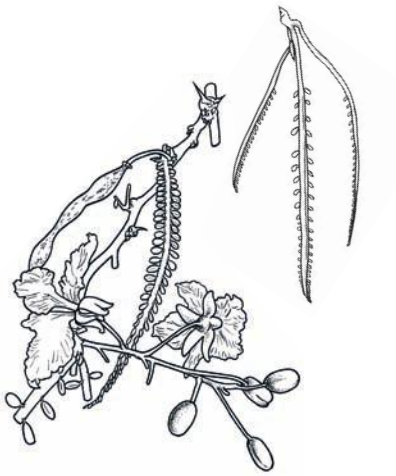
IMPACTS
Grows rapidly, forming dense stands which displace native species. Leaf-litter and twig leachates inhibit the germination of native plant species (Florentine and Westbrooke, 2005). On Ascension Island, *N. glauca* may be displacing endemic species such as *Euphorbia origanoides* L. (Euphorbiaceae) (critically endangered) and *Anogramma ascensionis* (Hook.) Dielsby (Pteridaceae), dominating sites and altering ecological conditions (Gray *et al.*, 2005). It is also an alternative host for vectors of solanaceous crop diseases (Aviña-Padilla *et al.*, 2008). *N. glauca* is highly toxic. Its ingestion has reportedly caused the deaths of farmed ostriches (Botha *et al*., 2011). Birth defects in goats and sheep have also been reported (Panter *et al*., 2000). Some people have died after eating the plant, having mistaken it for spinach or another vegetable (Hassen *et al*., 2014).

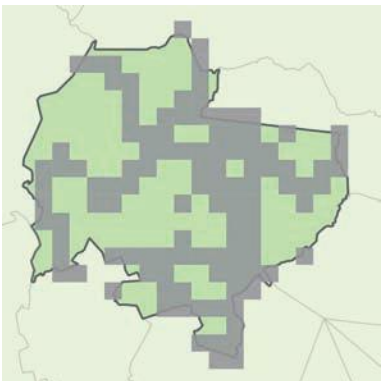
Nicotiana glauca Graham



Parkinsonia aculeata







FABACEAE FAMILY
Caesalpiniaceae

COMMON NAMES

English: horse bean, jelly bean tree, Jerusalem thorn, parkinsonian.
Lou: okwato
Orma: muk-bee

DESCRIPTION
Evergreen tree [2–6 (–10) m high]; stem smooth, hairless, greenish-yellow when young turning brown, branches zigzag and armed with stout spines (3–20 mm long) below each leaf.

Bark: Greenish-yellow turning brown, smooth.

Leaves: Light green, one-divided in young plants becoming twice-divided in older plants with 1–2 (3) pairs of very long, slender, drooping, flattened branchlets (20–40 cm long) each with 20–30 pairs of small egg-shaped to somewhat elongated leaflets with almost parallel sides [1–4 (–10) mm long and 1–2 mm wide].

Flowers: Yellow and fragrant (2–3 cm across) with red or brown dots on the largest petal, in slender elongated clusters (5–20 cm long) arising from the leaf forks.

Fruits: Pods (several seeded dry fruits that split open at maturity), green turning brown as they mature, narrow, elongated (3–13 cm long and 5–10 mm wide), swollen around each of the large seeds (9–15 mm long and 3–6 mm wide).

ORIGIN
Southern USA, Mexico, the Galápagos Islands, Bolivia, Peru, Paraguay, Uruguay and Argentina.

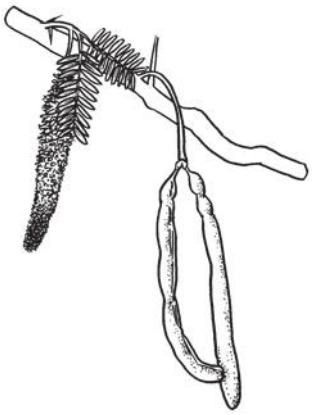
REASON FOR INTRODUCTION
Hedge/barrier, shade and ornament.

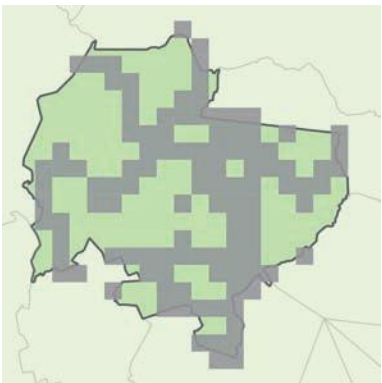
INVADES
Roadsides, disturbed land, drainage ditches, edges of irrigation channels, riversides, lowlands, floodplains, gullies and water courses.

IMPACTS
Forms large, impenetrable thickets, displacing native plant and animal species. In Australia, this weed already occupies more than 1 million hectares, and has the potential to invade more than three-quarters of mainland Australia. There, infestations have blocked or retarded water flows, increased erosion, lowered the water table, restricted access to land and to waterways, and blocked access by livestock to watering points, while also harbouring feral animals such as pigs – and contributing to additional mustering costs. The livestock carrying capacities of pastures have been reduced. The spines on these trees/shrubs can cause injuries to people and to livestock and wild animals. In New Caledonia, *P. aculeata* has been described as one of the single biggest threats to productivity and profitability (Swarbrick, 1997).

Parkinsonia aculeata L.

Prosopis juliflora





PEA FAMILY
Fabaceae; subfamily: Mimosaceae

COMMON NAMES
English: algorroba, ironwood, mesquite. Turkana: eterai. Kikuyu: mathenge. Somalia: mathebe.

DESCRIPTION
Evergreen shrub or tree with thorns/spines, multi-stemmed but occasionally single stemmed [3–5 (15) m high], twigs distinctively zigzag.

Bark: Thick, rough grey-green, scaly with age and armed with sharp thorns/spines (up to 5 cm long).

Leaves: Dark green, hairless or hairy, twice-divided, 1–3 (–4) pairs of leaf branchlets (3–11 cm long) each with 11–15 pairs of leaflets, narrow, somewhat elongated with parallel sides (6–23 mm long and 1.6–5.5 mm wide), with smooth margins, no terminal leaflet, leaves grow alternately on stem.

Flowers: Yellow, small, in cylindrical spikes (5–10 cm long and 1.5 cm side), solitary or in clusters near the leaf axils, fragrant.

Fruits: Pods (several seeded dry fruits that split open at maturity), green turning yellow as they mature, flat, slightly curved (8–29 cm long and 9–17 mm wide), containing 10–20 oval seeds (2–8 mm long).

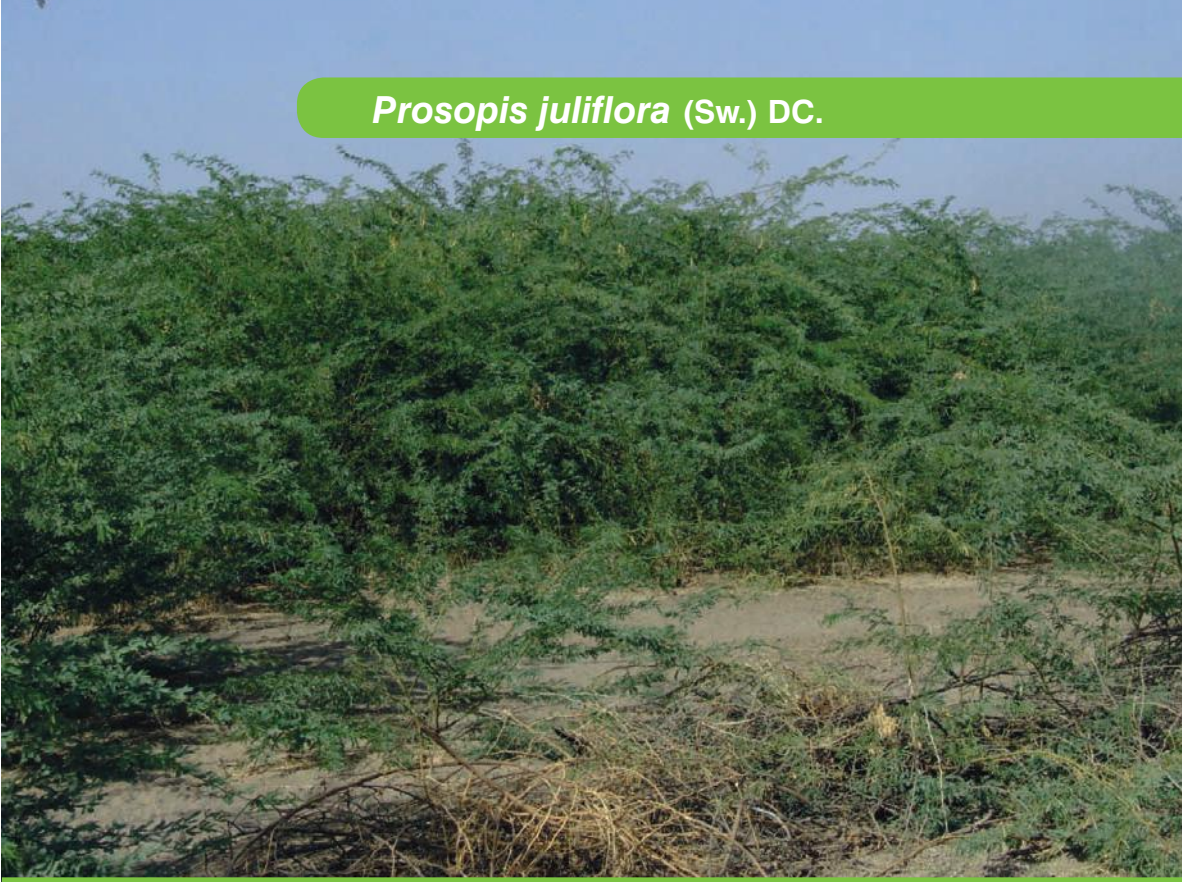
ORIGIN
Mexico, Costa Rica, El Salvador, Guatemala, Honduras, Nicaragua, Panama, Venezuela, Columbia and Ecuador.

REASON FOR INTRODUCTION
Fuelwood, timber, fodder, tannin, landscape restoration, windbreaks, shade, hedge/barrier and ornament.

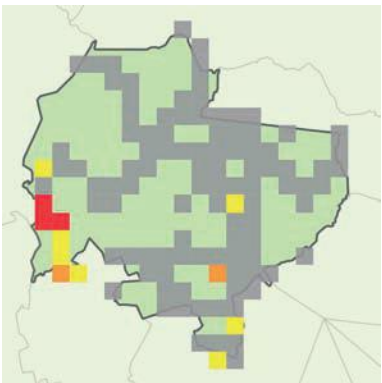
INVADES
Roadsides, disturbed land, wastelands, fallow land, drainage ditches, woodland edges/gaps, savannah, riparian vegetation, floodplains, gullies and sandy stream beds.

IMPACTS
Displaces native plant species and reduces the abundance and diversity of bird and other animal species. In Ethiopia, *P. juliflora* has reduced understorey basal cover for perennial grasses and reduced the number of grass species from seven to two (Kebede and Coppock, 2015). By transforming habitats and eliminating pasture species, it threatens the survival of Grévy's zebra (*Equus grevyi*) in invaded areas (Kebede and Coppock, 2015). Other negative impacts include encroachment on to paths, villages, homes, water sources, crop- and pasturelands; and injuries inflicted by the thorns (Maundu *et al*., 2009). Infestations have contributed to the abandonment of agricultural land, homes and small villages. The pollen has been identified as a major allergen (Killian and McMichael, 2004). In semi-arid parts of Africa, *P. juliflora* has depleted the natural resources on which thousands of people depend, spawning conflict between communities over the diminishing resources.

Prosopis juliflora (Sw.) DC.



Solanum mauritianum



TOMATO FAMILY
Solanaceae

COMMON NAMES

English: bugweed, nightshade, tobacco weed, wild tobacco, woolly nightshade

DESCRIPTION
Branched shrub or small tree [1.5–4 (–10) m high]; all parts except older stems covered with fine hairs; one or two ear-shaped leafy structures at base of leaf stalks.

Bark: Pale, greenish-brown, smooth, speckled.

Leaves: Dull green and velvety above, white-felty beneath, tobacco-like, egg-shaped or oval (7.5–40 cm long and 3–15 cm wide) with pointed tips, emitting a strong smell when bruised.

Flowers: Purple or lilac blue (15–25 mm across), pale star-shaped area at base, located in clusters of 25–100 flowers at the end of branches, on velvety stalks (3–18 cm long).

Fruits: Berries (fleshy fruits that don't open at maturity), green turning dull yellow as it matures, round (10–15 mm across), in groups of 20–80.

ORIGIN
Argentina, Brazil, Paraguay and Uruguay.

REASON FOR INTRODUCTION
Ornament

INVADES
Roadsides, wasteland, disturbed land, plantations, forest edges/gaps, woodland edges/gaps, riparian vegetation and gullies.

IMPACTS
Infestations displace native plant and animal species (Wells *et al*., 1986). Seed dispersers, mainly Rameron (African olive) pigeons (*Columba arquatrix* Temminck), by switching their diets from native plants in favour of *S. mauritianum*, have helped to spread the weed, adding to the number of invaded habitats and further reducing the abundance of native plant species (Oatley, 1984). *Ocotea bullata* (Burch.) Meyer in Drege (Lauraceae), for example, now an endangered species in natural forests, has suffered, not only through inappropriate utilization, but also because Rameron pigeons no longer disperse its seeds adequately (Pooley, 1993; Scott-Shaw, 1999). Bugweed has been found to have negative impacts, too, on some ground-dwelling invertebrates (Florentine and Westbrooke, 2003). In commercial forestry plantations, bugweed retards the growth of young pine trees and causes deformation of their stems (Hinze, 1985). Bugweed fruits are also alternative hosts for fruit flies and other major pests of deciduous and tropical fruit. The plant, if consumed, is also toxic to livestock. Fatalities have been reported among pigs and cattle in Queensland, Australia (Everist, 1974; Van Dyck, 1979). The fine hairs (trichomes) on the stems and leaves are an irritant, and can cause respiratory problems (Henderson, 2001).

Solanum mauritianum Scop.

Useful Websites

African Convention on the Conservation of Nature and Natural Resources
(**www.au.int/**)

BioNet-EAFRINET – Keys and Factsheets – Invasive Plants
(**http://keys.lucidcentral.org/keys/v3/eafrinet/plants.htm**)

CABI Invasive Species Compendium (ISC)
(**www.cabi.org/isc**)

Convention on Biological Diversity (CBD)
(**www.cbd.int/**)

Convention on Wetlands of International Importance (RAMSAR)
(**www.ramsar.org**)

Convention on the Establishment of the Lake Victoria Fisheries Organisation
(**www.kenyalaw.org**)

Environmental Weeds of Australia
(**http://keyserver.lucidcentral.org/weeds/data/media/Html/index.htm#A**)

Forest Invasive Species Network for Africa (FISNA)
(**www.fao.org/forestry/fisna/en/**)

Global Invasive Species Database (GISD)
(**http://www.iucngisd.org/gisd/**)

International Plant Protection Convention (IPPC)
(**www.ippc.int/**)

New Partnership for Africa's Development (NEPAD)
(**www.nepad.org/**)

New South Wales WeedWise (NSW WeedWise)
(**weeds.dpi.nsw.gov.au/Weeds/Details/**)

Pacific Island Ecosystems at Risk (PIER)
(**www.hear.org/pier/**)

Phytosanitary Convention for Africa
(**www.au.int**)

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Appendix A

Status (Pr.-present; Nt.-naturalized; In.-invasive) of exotic species recorded during surveys in Laikipia County, that were probably intentionally introduced, and that are also known to be naturalized or invasive elsewhere (outside of Laikipia County). Please note that current status in Laikipia County may not reflect actual status, because not all of Laikipia was surveyed, and as such some species may be naturalized or invasive in areas not covered. It is also extremely likely that there are many other exotic species present in Laikipia County, that are naturalized or invasive elsewhere, that were not recorded during these surveys.

Species	Family	Origin	Pr.	Nt.	In.	Naturalized or invasive		
						Elsewhere in Kenya	In Africa outside of Kenya	Outside of Africa
Hypoestes phyllostachya Baker	Acanthaceae	Madagascar – tropical	Yes	Yes	No	Naturalized	Naturalized	?Naturalized
Thunbergia grandiflora (Roxb. ex Rottl.) Roxb.	Acanthaceae	Asia – tropical	Yes	Yes	No	Invasive	Invasive	Invasive
Sambucus nigra L. ssp. *canadensis* (L.) R. Bolli	Adoxaceae	America – nth temperate	Yes	No	No	Naturalized	Invasive	Invasive
Agave americana L.	Agavaceae	America – tropical	Yes	Yes	Yes	Invasive	Invasive	Invasive
A. angustifolia Haw.	Agavaceae	America – tropical	Yes	Yes	No	Invasive	Invasive	Invasive
A. attenuata Salm-Dyck	Agavaceae	America – tropical	Yes	No	No	No	No	?Naturalized
A. sisalana Perrine	Agavaceae	America – tropical	Yes	Yes	Yes	Invasive	Invasive	Invasive
Furcraea foetida (L.) Haw.	Agavaceae	America – tropical	Yes	Yes	Yes	Invasive	Invasive	Invasive
Aptenia cordifolia (L.f) Schwantes	Aizoaceae	Africa – sth temperate	Yes	No	No	No	No	Invasive
Carpobrotus edulis (L.) N.E. Br	Aizoaceae	Africa – sth temperate	Yes	No	No	No	No	Invasive
Agapanthus praecox ssp. orientalis (F.M. Leight.) F.M. Leight.	Amaryllidaceae	Africa – sth temperate	Yes	No	No	No	No	Invasive
Allium neapolitanum Cirillo	Amaryllidaceae	America – tropical	Yes	Yes	No	Invasive	Invasive	Invasive
Schinus molle L.	Anacardiaceae	America – tropical	Yes	No	No	No	Invasive	Invasive
S. terebinthifolius Raddi	Anacardiaceae	America – tropical	Yes	No	No	No	Invasive	Invasive
Foeniculum vulgare Mill.	Apiaceae	Mediterranean – nth temperate	Yes	Yes	No	Invasive	Invasive	Invasive
Allamanda cathartica L.	Apocynaceae	America – tropical	Yes	No	No	No	No	Invasive
Cascabela thevetia (L.) Lippold	Apocynaceae	America – tropical	Yes	No	No	Invasive	Invasive	Invasive
Catharanthus roseus (L.) G.Don	Apocynaceae	Madagascar – tropical	Yes	Yes	Yes	Invasive	Invasive	Invasive
Nerium oleander L.	Apocynaceae	Mediterranean – nth temperate	Yes	No	No	No	Invasive	Invasive
?Vinca major L.	Apocynaceae	Mediterranean – nth temperate	Yes	No	No	Naturalized	Invasive	Naturalized
Monstera deliciosa Liebm.	Araceae	America – tropical	Yes	No	No	No	Naturalized	Naturalized
Pistia stratiotes L.**	Araceae	America – tropical	No	No	No	Invasive	Invasive	Invasive
Hedera helix L.	Araliaceae	Eurasia – nth temperate	Yes	No	No	No	Naturalized	Invasive
Schefflera actinophylla (Endl.) Harms	Araliaceae	Australasia – tropical	Yes	No	No	No	Naturalized	Invasive
Calotropis procera (Aiton) W.T. Aiton*	Asclepiadaceae	Africa – tropical	Yes	Yes	No	Invasive	Invasive	Invasive

Species	Family	Origin	Pr.	Nt.	In.	Naturalized or invasive		
						Elsewhere in Kenya	In Africa outside of Kenya	Outside of Africa
Asparagus aethiopicus L.	Asparagaceae	Africa – sth temperate	Yes	No	No	No	No	Invasive
Sansevieria trifasciata Prain	Asparagaceae	Africa – tropical	Yes	No	No	?No	Naturalized	Invasive
Ageratum conyzoides L.	Asteraceae	America – tropical	Yes	Yes	Yes	Invasive	Invasive	Invasive
Cirsium vulgare (Savi) Ten.	Asteraceae	Eurasia – nth temperate	Yes	Yes	Yes	Invasive	Invasive	Invasive
Cosmos bipinnatus Cav.	Asteraceae	America – tropical	Yes	?Yes	No	Naturalized	Invasive	Invasive
Dahlia imperialis Roezl ex Ortgies	Asteraceae	America – tropical	Yes	Yes	No	Invasive	Naturalized	?Naturalized
Erigeron karvinskianus DC. [Illegitimate]	Asteraceae	America – tropical	Yes	No	No	Naturalized	Invasive	Invasive
Euryops chrysanthemoides (DC.) B. Nord.	Asteraceae	Africa – sth temperate	Yes	Yes	Yes	Invasive	Invasive	?Invasive
Parthenium hysterophorus L.	Asteraceae	America – tropical	Yes	Yes	Yes	Invasive	Invasive	Invasive
Senecio madagascariensis Poir	Asteraceae	Africa – sth temperate	Yes	Yes	No	Invasive	Invasive	Invasive
Sphagneticola trilobata (L.C. Rich.) Pruski	Asteraceae	America – tropical	Yes	No	No	Invasive	Invasive	Invasive
Tithonia diversifolia (Hemsl.) A. Gray	Asteraceae	America – tropical	Yes	Yes	Yes	Invasive	Invasive	Invasive
Xanthium strumarium L.	Asteraceae	America – tropical	Yes	Yes	Yes	Invasive	Invasive	Invasive
Zinnia peruviana (L.) L.	Asteraceae	America – sth temperate	Yes	No	No	Naturalized	Invasive	Invasive
?*Azolla filiculoides* Lam.	Azollaceae	America – tropical	Yes	Yes	Yes	Invasive	Invasive	Invasive
Dolichandra unguis-cati (L.) L.G. Lohmann	Bignoniaceae	America – tropical	Yes	No	No	Invasive	Invasive	Invasive
Jacaranda mimosifolia D. Don	Bignoniaceae	America – tropical	Yes	Yes	No	Naturalized	Invasive	Invasive
Podranea ricasoliana (Tanfani) Sprague	Bignoniaceae	Africa – sth temperate	Yes	Yes	No	Naturalized	?Naturalized	Invasive
Pyrostegia venusta (Ker Gawl.) Miers	Bignoniaceae	America – tropical	Yes	No	No	Naturalized	Invasive	Invasive
Tecoma capensis (Thunb.) Lindl.	Bignoniaceae	Africa – sth temperate	Yes	No	No	?Naturalized	?Naturalized	Invasive
Tecoma stans (L.) Juss. ex Kunth	Bignoniaceae	America – tropical	Yes	Yes	No	Invasive	Invasive	Invasive
Austrocylindropuntia subalata (Muelenpf.) Backeb.	Cactaceae	America – tropical	Yes	Yes	Yes	Invasive	Invasive	?Invasive
Cereus jamacaru DC.	Cactaceae	America – tropical	Yes	Yes	No	Invasive	Invasive	Invasive
Cylindropuntia imbricata (Haw.) F.M. Knuth	Cactaceae	America – tropical	Yes	Yes	No	No	Invasive	Invasive
Hylocereus undatus (Haw.) Britton & Rose	Cactaceae	America – tropical	Yes	No	No	Invasive	Invasive	Invasive
Opuntia engelmannii Salm-Dyck ex Engelm.	Cactaceae	N. America – nth temperate	Yes	Yes	Yes	?No	Invasive	Invasive
O. ficus-indica (L.) Mill.	Cactaceae	America – tropical	Yes	Yes	Yes	Invasive	Invasive	Invasive

Species	Family	Origin	Pr.	Nt.	In.	Naturalized or invasive		
						Elsewhere in Kenya	In Africa outside of Kenya	Outside of Africa
O. microdasys (Lehm.) Pfeiff.	Cactaceae	America – tropical	Yes	Yes	No	No	Invasive	Invasive
O. monacantha (Willd.) Haw.	Cactaceae	America – tropical	Yes	Yes	No	Invasive	Invasive	Invasive
O. stricta (Haw.) Haw.	Cactaceae	America – tropical	Yes	Yes	Yes	Invasive	Invasive	Invasive
Peniocereus serpentinus (Lag. & Rodr.) N.P. Taylor	Cactaceae	America – tropical	Yes	Yes	No	?No	Invasive	?Naturalized
Canna indica L.	Cannaceae	America – tropical	Yes	Yes	Yes	Invasive	Invasive	Invasive
C. × *generalis* L.H. Bailey & E.Z. Bailey	Cannaceae	America – tropical	Yes	No	No	Invasive	Invasive	Naturalized
Lonicera japonica Thunb.	Caprifiliaceae	Asia – nth temperate	Yes	No	No	?Naturalized	Naturalized	Invasive
Casuarina cunninghamiana Miq.	Casuarinaceae	Australia – tropical	Yes	Yes	No	Invasive	Invasive	Invasive
Callisia fragrans (Lindl.) Woodson	Commelinaceae	America – tropical	Yes	No	No	?Invasive	?Naturalized	Invasive
C. repens (Jacq.) L.	Commelinaceae	America – tropical	Yes	No	No	?Invasive	Invasive	Invasive
Tradescantia pallida (Rose) D.R. Hunt	Commelinaceae	America – tropical	Yes	No	No	Naturalized	Naturalized	Invasive
T. zebrina Bosse	Commelinaceae	America – tropical	Yes	Yes	No	Invasive	Invasive	Invasive
Ipomoea cairica Sweet*	Convulvulaceae	Africa – tropical	Yes	Yes	Yes	Invasive	Invasive	Invasive
I. indica (Burm.) Merr.	Convolvulaceae	America – tropical	Yes	No	No	Invasive	Invasive	Invasive
Bryophyllum daigremontianum (Raym.-Hamet & H. Perrier) Berger	Crassulaceae	Madagascar – sth temperate	No	No	No	Naturalized	Naturalized	Naturalized
Bryophyllum delagoense (Eckl. & Zeyh.) Druce	Crassulaceae	Madagascar – sth temperate	Yes	Yes	Yes	Invasive	Invasive	Invasive
B. fedtschenkoi (Raym.-Hamet & H.Perrier) Lauz.-March.	Crassulaceae	Madagascar – sth temperate	Yes	Yes	Yes	Invasive	Naturalized	Naturalized
B. gastonis-bonnieri (Raym.-Hamet & H. Perrier) Lauz.-March	Crassulaceae	Madagascar – sth temperate	Yes	No	No	Naturalized	Naturalized	Naturalized
B. pinnatum (Lam.) Oken	Crassulaceae	Madagascar – tropical	Yes	Yes	No	Naturalized	Invasive	Invasive
B. proliferum Bowie ex Hook.	Crassulaceae	Madagascar – tropical	Yes	Yes	No	Invasive	Invasive	Naturalized
Crassula multicava Lem.	Crassulaceae	Africa – sth temperate	Yes	Yes	No	Naturalized	?Naturalized	Naturalized
C. ovata (Mill.) Druce	Crassulaceae	Africa – sth temperate	Yes	Yes	No	?Naturalized	?Naturalized	Invasive
C. sarmentosa Harv.	Crassulaceae	Africa – sth temperate	Yes	Yes	Yes	Invasive	Naturalized	Naturalized
C. tetragona L.	Crassulaceae	Africa – sth temperate	Yes	Yes	Yes	?Naturalized	No	No
Cotyledon orbiculata L.	Crassulaceae	Africa – sth temperate	Yes	No	No	?Naturalized	?No	Invasive
Kalanchoe beharensis Drake	Crassulaceae	Madagascar – sth temperate	Yes	Yes	No	Naturalized	Naturalized	Invasive
Cupressus lusitanica Mill.	Cupressaceae	America – tropical	Yes	No	No	No	Naturalized	Invasive
Euphorbia cotinifolia L.	Euphorbiaceae	America – tropical	Yes	No	No	No	Naturalized	Invasive

Species	Family	Origin	Pr.	Nt.	In.	Naturalized or invasive		
						Elsewhere in Kenya	In Africa outside of Kenya	Outside of Africa
E. milii var. *splendens* (Bojer ex Hook.) Ursch & Leandri	Euphorbiaceae	Madagascar – sth temperate	Yes	No	No	No	?Naturalized	No
E. pulcherrima Willd. Ex Klotzsch	Euphorbiaceae	America – tropical	Yes	No	No	No	?Naturalized	No
Jatropha curcas L.	Euphorbiaceae	America – tropical	Yes	No	No	?Invasive	Invasive	Invasive
J. gossypiifolia L.	Euphorbiaceae	America – tropical	Yes	Yes	No	Invasive	Invasive	Invasive
Ricinus communis L.*	Euphorbiaceae	Africa – tropical	Yes	Yes	Yes	Invasive	Invasive	Invasive
Acacia mearnsii De Wild.	Fabaceae	Australia – sth temperate	Yes	Yes	Yes	Invasive	Invasive	Invasive
A. melanoxylon R. Br.	Fabaceae	Australia – sth temperate	Yes	Yes	Yes	Invasive	Invasive	Invasive
A. podalyriifolia G. Don	Fabaceae	Australia – sth temperate	Yes	No	No	Invasive	Invasive	Invasive
Acrocarpus fraxinifolius Arn.	Fabaceae	Asia – tropical	Yes	No	No	Invasive	Invasive	Invasive
Bauhinia variegata L.	Fabaceae	Asia – tropical	Yes	No	No	Naturalized	Invasive	Invasive
Caesalpinia decapetala (Roth) Alston	Fabaceae	Asia – tropical	Yes	Yes	Yes	Invasive	Invasive	Invasive
Calliandra houstoniana (Mill.) Standl. var. *calothyrsus* (Meisn.) Barneby	Fabaceae	America – tropical	Yes	No	No	Invasive	Invasive	Invasive
Delonix regia (Hook.) Raf.	Fabaceae	Madagascar – tropical	Yes	No	No	?Naturalized	Invasive	Invasive
Leucaena leucocephala (Lam.) de Wit	Fabaceae	America – tropical	Yes	No	No	Invasive	Invasive	Invasive
Parkinsonia aculeata L.	Fabaceae	America – tropical	No	No	No	Invasive	Invasive	Invasive
Pithecellobium dulce (Roxb.) Benth.	Fabaceae	America – tropical	Yes	No	No	Naturalized	Naturalized	Naturalized
Prosopis juliflora (Sw.) DC.	Fabaceae	America – tropical	No	No	No	Invasive	Invasive	Invasive
Senna didimobotrya (Fresen.) Irwin & Barneby*	Fabaceae	Africa – tropical	Yes	Yes	Yes	Invasive	Invasive	Invasive
S. obtusifolia (L.) H.S. Irwin & Barneby	Fabaceae	America – tropical	Yes	No	No	Invasive	Invasive	Invasive
S. occidentalis (L.) Link	Fabaceae	America – tropical	Yes	Yes	Yes	Invasive	Invasive	Invasive
S. septemtrionalis (Viv.) H.S. Irwin & Barneby	Fabaceae	America – tropical	Yes	Yes	No	Invasive	Invasive	Invasive
S. siamea (Lam.) H.S. Irwin & Barneby	Fabaceae	Asia – tropical	Yes	No	No	Invasive	Invasive	Invasive
S. spectabilis (DC.) H.S. Irwin & Barneby	Fabaceae	America – tropical	Yes	No	No	Invasive	Invasive	Invasive
?*Crocosmia x crocosmiiflora* (Lem.) N.E. Brown	Iridaceae	Africa – sth temperate	Yes	No	No	?Naturalized	Invasive	Invasive
Dietes grandiflora N.E. Br.	Iridaceae	Africa – sth temperate	Yes	No	No	No	?No	Invasive
Salvia coccinea Buc'hoz ex Etl.	Lamiaceae	America – tropical	Yes	Yes	Yes	Invasive	Naturalized	Invasive
S. leucantha Cav.	Lamiaceae	America – tropical	Yes	Yes	No	Naturalized	Naturalized	Naturalized

Species	Family	Origin	Pr.	Nt.	In.	Naturalized or invasive		
						Elsewhere in Kenya	In Africa outside of Kenya	Outside of Africa
Azadirachta indica A. Juss.	Meliaceae	Asia – nth temperate	Yes	No	No	Invasive	Invasive	Invasive
Melia azedarach L.	Meliaceae	Australasia – tropical	Yes	No	No	Naturalized	Invasive	Invasive
Ficus benjamina L.	Moraceae	Australasia – tropical	Yes	No	No	No	No	Invasive
F. elastica Roxb. Ex Hornem	Moraceae	Asia – nth temperate	Yes	No	No	No	No	Invasive
F. pumila L.	Moraceae	Asia – tropical	Yes	No	No	No	No	Invasive
Morus spp. ***	Moraceae	Asia – nth temperate	Yes	No	No	?Naturalized	Invasive	Invasive
Eucalyptus spp. ***	Myrtaceae	Australia – sth temperate	Yes	Yes	No	Naturalized	Invasive	Invasive
Melaleuca armillaris (Sol. ex Gaertn.) Sm.	Myrtaceae	Australia – sth temperate	Yes	No	No	No	No	?Naturalized
M. citrina (Curtis) Dum. Cours	Myrtaceae	Australia – sth temperate	Yes	No	No	No	?Naturalized	No
Callistemon viminalis (Sol. ex Gaertn.) Byrnes	Myrtaceae	Australia – sth temperate	Yes	No	No	No	Naturalized	Invasive
Psidium guajava L.	Myrtaceae	America – tropical	Yes	No	No	Invasive	Invasive	Invasive
Nephrolepis cordifolia (L.) C. Presl	Nephrolepidaceae	Australia – tropical	Yes	No	No	Naturalized	Invasive	Invasive
Bougainvillea spp.***	Nyctaginaceae	America – tropical	Yes	No	No	Naturalized	Naturalized	Invasive
Mirabilis jalapa L.	Nyctaginaceae	America – sth temperate	Yes	Yes	Yes	Invasive	Invasive	Invasive
Jasminum polyanthum Franch.	Oleaceae	Asia – nth temperate	Yes	No	No	Naturalized	Naturalized	Invasive
Argemone spp.***	Papaveraceae	America – tropical	Yes	Yes	Yes	Invasive	Invasive	Invasive
Passiflora edulis Sims	Passifloraceae	America – tropical	Yes	No	No	Naturalized	Invasive	Invasive
P. subpeltata Ortega	Passifloraceae	America – tropical	No	No	No	Invasive	Invasive	Invasive
Breynia disticha J.R. Forst. & G. Forst.	Phyllanthaceae	Oceania – tropical	Yes	No	No	No	Invasive	Invasive
Pinus patula Schiede ex Schltdl & Cham.	Pinaceae	America – tropical	Yes	No	No	Invasive	Invasive	Invasive
Plumbago auriculata Lam.	Plumbaginaceae	Africa – sth temperate	Yes	No	No	No	?No	?Naturalized
Antigonon leptopus Hook. & Arn.	Polygonaceae	America – tropical	Yes	No	No	Invasive	Invasive	Invasive
Eichhornia crassipes (Mart.) Solms	Pontederiaceae	America – tropical	Yes	No	No	Invasive	Invasive	Invasive
Pontederia cordata L.	Pontederiaceae	America – tropical	Yes	No	No	Naturalized	Invasive	Invasive
Grevillea robusta A. Cunn. ex R. Br.	Proteaceae	Australia – sth temperate	Yes	Yes	No	Naturalized	Invasive	Invasive
Cotoneaster pannosus Franch	Rosaceae	Asia – nth temperate	Yes	No	No	No	Invasive	Invasive
Eriobotrya japonica (Thunb.) Lindl.	Rosaceae	Asia – nth temperate	Yes	No	No	Naturalized	Invasive	Invasive
Pyracantha coccinea M. Roem.	Rosaceae	Eurasia – nth temperate	Yes	No	No	No	Invasive	Invasive
Dovyalis caffra (Hook. f. & Harv.) Sim	Salicaceae	Africa – sth temperate	Yes	No	No	Invasive	No	No
Salvinia molesta D.S. Mitch.	Salviniaceae	America – tropical	Yes	Yes	No	Invasive	Invasive	Invasive

Species	Family	Origin	Pr.	Nt.	In.	Naturalized or invasive		
						Elsewhere in Kenya	In Africa outside of Kenya	Outside of Africa
Buddleja madagascariensis Lam.	Scrophulariaceae	Madagascar – tropical	Yes	No	No	?Naturalized	Naturalized	Invasive
Brugmansia suaveolens (Humb. & Bonpl. ex Willd.) Bercht. & J.Presl	Solanaceae	America – tropical	Yes	No	No	Invasive	Invasive	Invasive
Cestrum aurantiacum Lindl.	Solanaceae	America – tropical	Yes	Yes	Yes	Invasive	Invasive	Invasive
C. elegans (Brongn. Ex Neumann) Schltdl.	Solanaceae	America – tropical	Yes	No	No	Invasive	Invasive	Invasive
Datura stramonium L.	Solanaceae	America – tropical	Yes	Yes	Yes	Invasive	Invasive	Invasive
Nicotiana glauca Graham	Solanaceae	South America – sth temperate	Yes	Yes	Yes	Invasive	Invasive	Invasive
Solanum campylacanthum Hochst. ex A. Rich.*	Solanaceae	Africa – tropical	Yes	Yes	Yes	Invasive	Invasive	Naturalized
S. mauritianum Scop.	Solanaceae	America – tropical	Yes	Yes	Yes	Invasive	Invasive	Invasive
S. seaforthianum Andrews	Solanaceae	America – tropical	Yes	No	No	Invasive	Invasive	Invasive
Duranta erecta L.	Verbenaceae	America – tropical	Yes	No	No	Naturalized	Invasive	Naturalized
Lantana camara L.	Verbenaceae	America – tropical	Yes	Yes	Yes	Invasive	Invasive	Invasive
Stachytarpheta jamaicensis (L.) Vahl	Verbenaceae	America – tropical	Yes	No	No	Invasive	Invasive	Invasive
Verbena bonariensis L.	Verbenaceae	America – tropical	Yes	Yes	Yes	Invasive	Invasive	Naturalized

*Considered to be an indigenous species

**Included in the Field Guide but not seen in Laikipia County

***Species within these genera are known to be naturalized and invasive

? Uncertainty with regard to identification and categorization as naturalized or invasive

Appendix B

Biological control agents that have established in eastern Africa or elsewhere on some of the species of plants included in this Field Guide (from Winston et al., 2014 and R.L. Winston, *pers. comm.*)

Species	Plant family	Agent family	Agent species	Country/countries established
Pistia stratiotes L.	Araceae	Curculionidae	*Neohydronomus affinis* Hustache	Australia, Benin, Botswana, Cote d'Ivoire, Ghana, Kenya, Morocco, Mozambique, Nigeria, Papua New Guinea, Puerto Rico*, Republic of Congo, Republic of South Africa, République Togolaise, Senegal, United States of America, Vanuatu, Zambia, Zimbabwe
		Noctuidae	*Spodoptera pctinicornis* (Hampson)	Thailand
Cirsium vulgare (Savi) Ten.	Asteraceae	Syrphidae	*Cheilosia grossa* (Fallén)	United States of America
		Curculionidae	*Rhinocyllus conicus* (Frölich)	Australia, Canada, Republic of South Africa, United States of America
		Curculionidae	*Trichosirocalus horridus* (Panzer)	Australia, United States of America
		Tephiritidae	*Urophora stylata* (Fabricius)	Australia, Canada, New Zealand, United States of America
Parthenium hysterophorus L.	Asteraceae	Bucculatricidae	*Bucculatrix pathenica* Bradley	Australia
		Sesiidae	*Carmenta* sp. nr *ithacae* (Beutenmüller)	Australia
		Curculionidae	*Conotrachelus albocinereus* Fiedler	Australia
		Tortricidae	*Epiblema strenuana* (Walker)	Australia
		Curculionidae	*Listronotus setosipennis* (Hustache)	Australia, Republic of South Africa*
		Tortricidae	*Platphalonidia mystica* (Razowski & Becker)	Australia
		Pucciniales	*Puccinia abrupta* Dietel & Holw. var. *partheniicola* (H.S. Jacks.) Parmelee	Australia, Ethiopia, India, Kenya, Mauritius, Nepal, People's Republic of China, Republic of South Africa, Tanzania
		Pucciniales	*Puccinia xanthii* Schwein. var *parthenii-hysterophorae* Seier, H. C. Evans & Á. Romero.	Australia, Republic of South Africa
		Curculionidae	*Smicronyx lutulentus* Dietz	Australia
		Delphacidae	*Stobaera concinna* (Stål)	Australia
		Chrysomelidae	*Zygogramma bicolorata* Pallister	Australia, Ethiopia*, India, Nepal, Pakistan, Republic of South Africa*, Tanzania*, Vanuatu*
Xanthium strumarium L.	Asteraceae	Tortricidae	*Epiblema strenuana* (Walker)	Australia
		Tephritidae	*Euaresta aequalis* Loew	Australia
		Cerambycidae	*Mecas cana* ssp. satumina (LeConte)	Australia*
		Cerambycidae	*Nupserha vexator* (Pascoe)	*Australia*
		Chrysomelidae	*Ophraella communa* LeSage	Japan

Species	Plant family	Agent family	Agent species	Country/countries established
		Pucciniales	*Puccinia xanthii* Schweinitz	Australia
Azolla filiculoides Lam.	Azollaceae	Erirhinidae	*Stenopelmus rufinasus* Gyllenhal	Belgium, England, France, Germany, Hungary, Italy, Mozambique, Netherlands, Northern Ireland, Portugal, Republic of Ireland, Republic of South Africa, Slovakia, Spain, Ukraine, Wales, Zimbabwe
Cereus jamacaru DC.	Cactaceae	Pseudococcidae	*Hypogeococcus festerianus* (Lizer y Trelles)	Republic of South Africa
		Cerambycidae	*Nealcidion cereicola* (Fisher)	Republic of South Africa
Cylindropuntia imbricata (Haw.) F.M. Knuth	Cactaceae	Dactylopiidae	*Dactylopius tomentosus* (Lamark)	Australia, Republic of South Africa
		Dryophthridae	*Metamasius spinoalae* (Gyllenhal)	Republic of South Africa
Opuntia elatior Mill.	Cactaceae	Dactylopiidae	*Dactylopius opuntiae* (Cockerell)	India, Indonesia
Opuntia engelmannii Salm-Dyck ex Engelm.	Cactaceae	Pyralidae	*Cactoblastis cactorum* (Berg)	Antigua, Republic of South Africa
		Dactylopiidae	*Dactylopius opuntiae* (Cockerell)	Republic of South Africa
Opuntia ficus-indica (L.) Mill.	Cactaceae	Pyralidae	*Cactoblastis cactorum* (Berg)	Cuba, Hawaii USA, Puerto Rico, Republic of South Africa, U.S. Virgin Islands
		Dactylopiidae	*Dactylopius opuntiae* (Cockerell)	Hawaii USA, Republic of South Africa, Spain
		Hypocreales	*Fusarium oxysporum* Schlecktendahl	Hawaii USA
		Cerambycidae	*Lagocheirus funestus* Thomson	Hawaii USA, Republic of South Africa
		Dryophthoridae	*Metamasius spinolae* (Gyllenhal)	Republic of South Africa
Opuntia monacantha (Willd.) Haw.	Cactaceae	Pyralidae	*Cactoblastis cactorum* (Berg)	Cuba, Mauritius
		Dactylopiidae	*Dactylopius ceylonicus* (Green)	Australia, India, Mauritius, Republic of South Africa, Sri Lanka
			Dactylopius confusus (Cockerell)	Australia
		Dactylopiidae	*Dactolopius opuntiae* (Cockerell)	Mauritius
Opuntia stricta (Haw.) Haw.	Cactaceae	Pyralidae	Cactoblastis cactorum (Berg)	Antigua, Australia, Bahamas, Cayman Islands, Cuba, Federation of St Kitts and Nevis, Guadeloupe, Jamaica, Montserrat, New Caledonia, Puerto Rico, Republic of South Africa, U.S. Virgin Islands
		Coreidae	Chelinidea tabulata (Burmeister)	Australia
			Chelinidea vittiger Uhler	Australia*
		Dactylopiidae	Dactylopius confusus Cockerell	Australia
			Dactolopius opuntiae (Cockerell)	Australia, Federation of St Kitts and Nevis, India, Kenya, Republic of South Africa, Sri Lanka
		Cerambycidae	Moneilema blapsides (Newman) ssp. ulkei Horn	Australia
		Cerambycidae	Moneilema variolare Thomson	Australia

Species	Plant family	Agent family	Agent species	Country/countries established
		Pyralidae	Olycella junctolineella (Hulst)	Australia
Acacia mearnsii De Wild.	Fabaceae	Agaricales	Cylindrobasidium laeve (Pers.)	Republic of South Africa
		Cecidomyiidae	Dasineura rubiformis Kolesik	New Zealand, Republic of South Africa,
		Curculionidae	Melanterius maculatus Lea	Republic of South Africa
Acacia melanoxylon R. Br.	Fabaceae	Curculionidae	Melanterius acaciae Lea	Republic of South Africa
Caesalpinia decapetala (Roth) Alston	Fabaceae	Chrysomelidae	Sulcobruchus subsuturalis (Pic)	Republic of South Africa
Parkinsonia aculeata L.	Fabaceae	Chrysomelidae	Mimosestes ulkei (Horn)	Australia*
		Chrysomelidae	Penthobruchus germaini (Pic)	Australia
		Miridae	Rhinacloa callicrates Herring	Australia
Prosopis juliflora (Sw.) DC.	Fabaceae	Chrysomelidae	Algarobius bottimeri Kingsolver	Australia
		Chrysomelidae	Algarobius prosopis (Le Conte)	Ascension Island, Australia, Botswana, Egypt, Namibia, Oman, Republic of South Africa, Saudi Arabia, United Arab Emirates, Yemen
		Gelechiidae	Evippe sp. # 1	Australia
		Psyllidae	Heteropsylla reducta Caldwell & Martorell	Ascension Island
		Chrysomelidae	Neltumius arizonensis (Schaeffer)	Ascension Island, Botswana, Namibia, Republic of South Africa
		Psyllidae	*Prosopidopsylla flava* Burckhardt	Australia,
		Miridae	*Rhinocloa* sp.	Ascension Island
Eichhornia crassipes (Mart.) Solms	Pontederiaceae	Hypocreales	*Acremonium zonatum* (Sawada) W. Gams	Mexico
		Pleosporales	*Alternaria eichhorniae* Nag Raj & Ponnappa	Egypt, Republic of South Africa
		Noctuidae	*Bellura densa* (Walker)	United States of America
		Capnodiales	*Cercospora piaropi* Tharp	Mexico, United States of America, Republic of South Africa
		Acrididae	*Cornops aquaticum* Bruner	Republic of South Africa*
		Miridae	*Eccritotarsus catarinensis* (Carvalho)	Ghana, Malawi, Republic of South Africa
		Delphacidae	*Megamelus scutellaris* Berg	Republic of South Africa, United States of America,
		Erirhinidae	*Neochetina bruchi* Hustache	Argentina, Australia, Benin, Bolivia, Burkina Faso, Cote d'Ivoire, Cuba, Egypt, Ghana, Honduras, India, Indonesia, Kenya, Malawi, Malaysia, Mali, Mexico, Mozambique, Niger Republic*, Nigeria, Panama*, Papua New Guinea, People's Republic of China, Philippines*, Republic of Congo, Republic of South Africa, République Togolaise, Rwanda, South Sudan, Sri Lanka, Sudan, Tanzania, Thailand, Uganda, United States of America, Vanuatu, Vietnam, Zambia, Zimbabwe

Species	Plant family	Agent family	Agent species	Country/countries established
		Erirhinidae	*Neochetina eichhorniae* Warner	Australia, Benin, Bolivia, Burkina Faso, Cote d'Ivoire, Cuba, Egypt, Fiji, Ghana, Honduras, India, Indonesia, Kenya, Malawi, Malaysia, Mali, Mexico, Mozambique, Myanmar, Nauru*, Niger Republic, Nigeria, Papua New Guinea, People's Republic of China, Philippines*, Republic of Congo, Republic of South Africa, République Togolaise, Rwanda, Solomon Islands, South Sudan, Sri Lanka, Sudan, Tanzania, Thailand, Uganda, United States of America, Vanuatu, Vietnam*, Zambia, Zimbabwe
		Crambidae	*Niphograpta albiguttalis* (Warren)	Australia, Benin, Cuba, Ghana, Kenya, Malawi*, Malaysia, Mexico, Nigeria, Panama*, Puerto Rico, Republic of South Africa, South Sudan, Thailand, United States of America, Zimbabwe
		Galumnidae	*Orthogalumna terebrantis* Wallwork	Cuba, India, Jamaica, Malawi, Mozambique, Republic of South Africa, United States of America, Zambia, Zimbabwe
		Crambidae	*Xubida infusella* (Walker)	Australia, Papua New Guinea*, Thailand
Salvinia molesta D.S. Mitch.	Salviniaceae	Erirhinidae	*Cyrtobagous salviniae* Calder & Sands	Australia, Botswana, Cote d'Ivoire, Fiji, Ghana, India, Indonesia, Kenya, Malaysia, Mali, Mauritania, Namibia, Papua New Guinea, Philippines, Republic of Congo, Republic of South Africa, République Togolaise, Senegal, Sri Lanka, Zambia, Zimbabwe
			Cyrtobagous singularis Hustache	Botswana, Fiji, Zambia, Zimbabwe
		Pauliniidae	*Paulinia acuminata* (De Geer)	Fiji, Mozambique, Zambia, Zimbabwe
		Crambidae	*Samea multiplicalis* (Guenée)	Australia, Fiji
Solanum mauritianum Scop.	Solanaceae	Curculionidae	*Anthonomus santacruzi* Hustache	Republic of South Africa
		Tingidae	*Gargaphia decoris* Drake	New Zealand, Republic of South Africa
Lantana camara L.	Verbenaceae	Eriophyidae	*Aceria lantanae* (Cook)	Australia*, Republic of South Africa, United States of America
		Membracidae	*Aconophora compressa* Walker	Australia
		Agromyzidae	*Calycomyza lantanae* (Frick)	Australia, Benin, Cambodia, Ethiopia, Federated States of Micronesia, Fiji, Guam, Indonesia, Kenya, La Réunion, Madagascar, Malaysia, Palau, Papua New Guinea, Philippines, Republic of South Africa, Singapore, Solomon Islands, Sri Lanka, Swaziland, Taiwan, Tanzania, Thailand, Timor Leste, Uganda, Vanuatu, Vietnam, Zimbabwe

Species	Plant family	Agent family	Agent species	Country/countries established
		Brentidae	*Coelocephalapion camarae* Kissinger	Republic of South Africa
		Gracillariidae	*Cremastobombycia lantanella* Busck	Hawaii USA
		Torticidae	*Crocidosema lantana* Busck	Australia, Federated States of Micronesia, Guam, Hawaii USA, India, Marshall Islands, Northern Mariana Islands, Palau, Republic of South Africa, Sri Lanka, Vanuatu, Zimbabwe
		Noctuidae	*Diastema tigris* Guenée	Mauritius
		Tephritidae	*Eutreta xanthochaeta* Aldrich	Hawaii USA
		Miridae	*Falconia intermedia* (Distant)	Australia, Republic of South Africa
		Erebidae	*Hypena laceratalis* Walker	Australia, Cape Verde Islands, Federated States of Micronesia, Fiji, Guam, Hawaii USA, Mauritius, New Caledonia, Northern Mariana Islands, Papua New Guinea, Philippines, Republic of South Africa, Taiwan*, Vanuatu
		Pterophoridae	*Lantanophaga pusillidactyla* (Walker)	Australia, Federated States of Micronesia, Guam, Hawaii USA, Hong Kong, India, Israel, Italy, Morocco, Myanmar, New Zealand, Northern Mariana Islands, Palau, Papua New Guinea, People's Republic of China, Philippines, Portugal, Republic of South Africa, Spain, Sri Lanka, Taiwan, Thailand, Timor Leste, Zambia, Zimbabwe
		Tingidae	*Leptobyrsa decora* Drake	Australia, Cook Islands*, Hawaii USA, Tonga*
		Chrysomelidae	*Longitarus bethae* Savini & Escalona	Republic of South Africa
		Noctuidae	*Neogalea sunia* (Guenée)	Australia, Hawaii USA, New Caledonia
		Chrysomelidae	*Octotoma championi* Baly	Australia
			Octotoma scabripennis Guérin-Méneville	Australia, Ghana, Guam, Hawaii USA, India, New Caledonia, Republic of South Africa, Solomon Islands*, Swaziland
		Agromyzidae	*Ophiomyia camarae* Spencer	Argentina, Ethiopia, Kenya, Madagascar, Mozambique, Swaziland, Tanzania, Zimbabwe,

Species	Plant family	Agent family	Agent species	Country/countries established
			Ophiomyia lantanae (Froggatt)	Argentina, Australia, Benin, Cook Islands* Ethiopia, Federated States of Micronesia, Fiji, French Polynesia, Ghana, Guam, Hawaii USA, Hong Kong, India, Indonesia, Kenya, La Réunion, Madagascar, Malaysia, Mozambique, Myanmar, New Caledonia, Northern Mariana Islands, Palau, Papua New Guinea, Philippines, Republic of South Africa, Samoa, Singapore, Sri Lanka, Swaziland, Taiwan, Tanzania, Thailand, Timor Leste, Tonga, Vanuatu, Vietnam, Zambia, Zimbabwe
		Ortheziidae	*Orthezia insignis* Browne	Ascension Island, Cape Verde Islands, Ethiopia, Hawaii USA, India, Kenya, La Réunion, Mauritius, Republic of South Africa, Sri Lanka, St Helena, Swaziland
		Capnodiales	*Passalora lantanae* var. lantanae (Chupp) U. Braun	Sri Lanka
		Pseudococcidae	*Phenacoccus parvus* Morrison	Australia
		Cerambycidae	*Plagiohammus spinipennis* (Thomson)	Australia
		Pucciniales	*Prospodium tuberculatum* (Spegazzini) Arthur	Australia
		Crambidae	*Salbia haemorrhoidalis* Guenée	Australia, Benin, Federated States of Micronesia, Fiji, Hawaii USA, Mauritius, Republic of South Africa, Uganda, Zambia
		Capnodiales	*Septoria* sp.	Hawaii USA
		Lycaenidae	*Strymon bazochii* (Godart)	Fiji, Hawaii USA*
		Tingidae	*Teleonemia scrupulosa* Stål	Ascension Island, Australia, Benin, Botswana, Federated States of Micronesia, Fiji, French Polynesia, Ghana, Guam, Hawaii USA, India, Indonesia, Kenya, La Réunion, Madagascar, Malaysia, Mauritius, Namibia, New Caledonia, Niue, Northern Mariana Islands, Palau Papua New Guinea, Philippines, Republic of South Africa, Samoa, Solomon Islands, Sri Lanka, St Helena, Swaziland, Tanzania, Thailand, Timor Leste, Tonga, Uganda, Vanuatu, Zambia, Zimbabwe
		Lycaenidae	*Tmolus echion* (L.)	Hawaii USA
		Chrysomelidae	*Uroplata fulvopustulata* Baly	Australia

Species	Plant family	Agent family	Agent species	Country/countries established
			Uroplata girardi Pic	Ascension Island, Australia, Cook Islands, Ethiopia, Federated States of Micronesia, Fiji, Ghana, Guam, Hawaii USA, India, Mauritius, New Caledonia, Niue, Northern Mariana Islands, Palau, Papua New Guinea, Philippines, Republic of South Africa, Samoa, Solomon Islands, St Helena*, Tanzania, Tonga, Trinidad and Tobago*, Uganda, Vanuatu, Zambia

*Establishment not yet confirmed

Appendix C

Herbicides registered or permissible with minor or emergency use permits in Australia by the Australian Pesticides and Veterinary Medicines Authority against some of the plant species included in this Field Guide (Joseph Vitelli; Department of Agriculture and Fisheries; Queensland Government; Australia; pers. comm.).

(Abbreviations used: g/L = grams/litre; g/kg = grams per kilogram)

Species	Family	Active constituent	Active constituent with concentration	A.I. (grams) per Litre	Method of Application
Agave americana L.	Agavaceae	Metsulfuron-methyl	Metsulfuron-methyl (600g/kg)	0.12g/L water + wetter	Foliar
		Triclopyr + Picloram	Triclopyr (240g/L) + Picloram (120g/L)	4g+2g/L diesel	Foliar
Agave angustifolia Haw.	Agavaceae	Triclopyr + Picloram	Triclopyr (240g/L) + Picloram (120g/L)	4g+2g/L diesel	Foliar
Agave sisalana Perrine	Agavaceae	Fluroxypyr	Fluroxypyr (333g/L)	6g/L diesel	Foliar
		Imazapyr	Imazapyr (250g/L)	1.25g/L water	Foliar
		Triclopyr + Picloram	Triclopyr (240g/L) + Picloram (120g/L)	4g+2g/L diesel	Foliar
Catharanthus roseus (L.) G. Don	Apocynaceae	Metsulfuron-methyl	Metsulfuron-methyl (600g/kg)	0.12g/L water + wetter	Foliar
		Triclopyr + Picloram	Triclopyr (300g/L) + Picloram (100g/L)	3.5g + 0.35g/L water	Foliar
Pistia stratiotes L.	Araceae	Diquat	Diquate (200g/L)	0.67g/L water	Foliar
		Flumioxazin	Flumioxazin (500g/L)	0.7g/L water	Foliar
		Glyphosate	Glyphosate (360g/L)	4.68g/L water	Foliar
Ageratum conyzoides L.	Asteraceae	Fluroxypyr	Fluroxypyr (333g/L)	0.25g/L water	Foliar
		Glufosinate ammonium	Glufosinate ammonium (200g/L)	1g/L water	Foliar
		Metsulfuron-methyl	Metsulfuron-methyl (600g/kg)	0.06g/L water + wetter	Foliar
Cirsium vulgare (Savi) Ten.	Asteraceae	Glyphosate	Glyphosate (360g/L)	3.6 g/L water	Foliar
Parthenium hysterophorus L.	Asteraceae	2,4-D	2,4-D Amine (500g/L)	2.0g/L water	Foliar
		2,4-D + Picloram	2,4-D (300g/L) + Picloram (75g/L)	0.6g + 0.15g/L water	Foliar
		Aminopyralid + Metsulfuron	Aminopyralid (375g/kg) + Metsulfuron (300g/kg)	0.375g + 0.09g/L water + wetter	Foliar
		Dicamba	Dicamba (500g/L)	2.75g/L water	Foliar
		Hexazinone	Hexazinone (250g/L)	0.175g/L water per 2 square meters	Foliar
		Metsulfuron-methyl	Metsulfuron-methyl (600g/kg)	0.03g/L water	Foliar
		Triclopyr + Metsulfuron	Triclopyr (75g/L) + Metsulfuron (28g/L)	0.15g + 0.06g/L water + wetter	Foliar
Tithonia diversifolia (Hemsl.) A. Gray	Asteraceae	Aminopyralid + Metsulfuron	Aminopyralid (375g/kg) + Metsulfuron (300g/kg)	0.075g + 0.06g/L water + wetter	Foliar
		Metsulfuron-methyl	Metsulfuron-methyl (600g/kg)	0.06g/L water + wetter	Foliar
		Triclopyr + Picloram + Aminopyralid	Triclopyr (300g/L) + Picloram (100g/L) + Aminopyralid (8g/L)	1.05g + 0.35g + 0.028g/L water	Foliar
Xanthium strumarium L.	Asteraceae	2,4-D	2,4-D Amine (625g/L)	1.9 g/L water	Foliar
		2,4-D + Picloram	2,4-D Amine (300g/L) + Picloram (75g/L)	200g + 50 g/L water	Foliar

Species	Family	Active constituent	Active constituent with concentration	A.I. (grams) per Litre	Method of Application
		Aminopyralid + Metsulfuron	Aminopyralid (375g/kg) + Metsulfuron (300g/kg)	0.0525g + 0.042g/L water + wetter	Foliar
		Dicamba	Dicamba (500g/L)	3.0 g/L water	Foliar
		Fluroxypyr	Fluroxypyr (333g/L)	0.15g/L water	Foliar
		Imazapyr	Imazapyr (250g/L)	0.625 g/L water	Foliar
		MCPA	MCPA (500g/L)	1.33g/L water	Foliar
		Metsulfuron-methyl	Metsulfuron-methyl (600g/kg)	0.038g/L water + wetter	Foliar
		Triclopyr + Metsulfuron	Triclopyr (75g/L) + Metsulfuron (28g/L)	0.15g + 0.06g/L water + wetter	Foliar
Azolla filiculoides Lam.	Azollaceae	Calcium dodecyl benzene sulfonate	Calcium dodecyl benzene sulfonate (300 g/L)	15g/L kerosene per 100m2	Foliar
		Diquat	Diquat (200g/L)	1.67g/L water	Foliar
Austrocylindropuntia cylindrica (Lam.) Backeb.	Cactaceae	MCMA	MSMA (800g/Kg)	18g/L water + wetter	Foliar
		Triclopyr + Picloram	Triclopyr (240g/L) + Picloram (120g/L)	4g +2g/L diesel	Foliar
Cereus jamacaru DC.	Cactaceae	Imazapyr	Imazapyr (250g/L)	Neat - Holes 2.5cm apart with 1mls per hole	Stem injection
		MSMA	MSMA (800g/Kg)	18g/L water +wetter	Foliar
		MSMA	MSMA (800g/Kg)	360g/L water-Holes 2.5cm apart with 2mls per hole	Stem injection
Cylindropuntia imbricata (Haw.) F.M. Knuth	Cactaceae	Metsulfuron-methyl	Metsulfuron-methyl (600g/kg)	0.12g/L water + wetter	Foliar
		MSMA	MSMA (800g/Kg)	18g/L water +wetter	Foliar
		Picloram + Fluroxypyr + Polysiloxane	Picloram (240g/L) + Fluroxypyr (333g/L) + 1020 (g/L) Polysiloxane	0.5g + 0.42g + 1.7g/L water	Foliar
Opuntia elatior Mill.	Cactaceae	Triclopyr + Picloram	Triclopyr (240g/L) + Picloram (120g/L)	4g +2g/L diesel	Foliar
		Triclopyr + Picloram + Aminopyralid	Triclopyr (300g/L) + Picloram (100g/L) + Aminopyralid (8g/L)	1.5g + 0.5g + 0.04g/L water	Foliar
Opuntia engelmannii Salm-Dyck ex Engelm.	Cactaceae	Triclopyr + Picloram	Triclopyr (240g/L) + Picloram (120g/L)	4g + 2g/L diesel	Foliar
		Triclopyr + Picloram + Aminopyralid	Triclopyr (300g/L) + Picloram (100g/L) + Aminopyralid (8g/L)	1.5g + 0.5g + 0.04g/L water	Foliar
Opuntia ficus-indica (L.) Mill.	Cactaceae	Triclopyr + Picloram	Triclopyr (240g/L) + Picloram (120g/L)	4g + 2g/L diesel	Foliar
		Triclopyr + Picloram + Aminopyralid	Triclopyr (300g/L) + Picloram (100g/L) + Aminopyralid (8g/L)	1.5g + 0.5g + 0.04g/L water	Foliar
Opuntia microdasys (Lehm.) Pfeiff.	Cactaceae	Triclopyr + Picloram	Triclopyr (240g/L) + Picloram (120g/L)	4g + 2g/L diesel	Foliar
		Triclopyr + Picloram + Aminopyralid	Triclopyr (300g/L) + Picloram (100g/L) + Aminopyralid (8g/L)	1.5g + 0.5g + 0.04g/L water	Foliar
Opuntia monacantha (Willd.) Haw.	Cactaceae	Triclopyr + Picloram	Triclopyr (240g/L) + Picloram (120g/L)	4g + 2g/L diesel	Foliar

Species	Family	Active constituent	Active constituent with concentration	A.I. (grams) per Litre	Method of Application
		Triclopyr + Picloram + Aminopyralid	Triclopyr (300g/L) + Picloram (100g/L) + Aminopyralid (8g/L)	1.5g + 0.5g + 0.04g/L water	Foliar
Opuntia stricta (Haw.) Haw.	Cactaceae	Amitrole + Ammonium Thiocyanate	Amitrole (250g/L) + Ammonium Thiocyanate (220g/L)	10g/L + wetter	Foliar
		Metsulfuron-methyl	Metsulfuron-methyl (600g/kg)	0.12g/L water + wetter	Foliar
		MSMA	MSMA (800g/Kg)	18g/L water + wetter	Foliar
		Picloram + Fluroxypyr + Polysiloxane	Picloram (240g/L) + Fluroxypyr (333g/L) + 1020 (g/L) Polysiloxane	0.5g + 0.42g + 1.7g/L water	Foliar
		Triclopyr + Picloram	Triclopyr (240g/L) + Picloram (120g/L)	4g + 2g/L diesel	Foliar
		Triclopyr + Picloram + Aminopyralid	Triclopyr (200g/L) + Picloram (100g/L) + Aminopyralid (25g/L)	5g + 2.5g + 0.625/L water	Foliar
		Triclopyr + Picloram + Aminopyralid	Triclopyr (300g/L) + Picloram (100g/L) + Aminopyralid (8g/L)	1.5g + 0.5g + 0.04g/L water	Foliar
Peniocereus serpentinus (Lag. & Rodr.) N.P. Taylor)	Cactaceae	MSMA	MSMA (800g/Kg)	18g/L water + wetter	Foliar
		Triclopyr + Picloram	Triclopyr (240g/L) + Picloram (120g/L)	4g + 2g/L diesel	Foliar
Bryophyllum delagoense (Eckl. & Zeyh.) Druce	Crassulaceae	Fluroxypyr	Fluroxypyr (333g/L)	1.2g/L water + wetter	Foliar
		Metsulfuron-methyl	Metsulfuron-methyl (600g/kg)	0.12g/L water + wetter	Foliar
		Metsulfuron-methyl + Glyphosate	Metsulfuron-methyl (600g/kg) + Glyphosate (360g/L)	0.06g/L + 0.72g/L water + wetter	Foliar
		Triclopyr + Picloram	Triclopyr (300 g/L) + Picloram (100 g/L)	1.5g/L + 0.5g/L water + wetter	Foliar
		Triclopyr + Picloram + Aminopyralid	Triclopyr (300g/L) + Picloram (100g/L) + Aminopyralid (8g/L)	1.5g/L + 0.5g/L + 0.04g/L water + wetter	Foliar
Bryophyllum fedtschenkoi (Raym.-Hamet & H. Perrier) Lauz.-March.	Crassulaceae	Metsulfuron-methyl	Metsulfuron-methyl (600g/kg)	0.12g/L water + wetter	Foliar
Bryophyllum pinnatum (Lam.) Oken	Crassulaceae	Fluroxypyr	Fluroxypyr (333g/L)	1.2g/L water + wetter	Foliar
		Metsulfuron-methyl	Metsulfuron-methyl (600g/kg)	0.12g/L water + wetter	Foliar
		Metsulfuron-methyl + Glyphosate	Metsulfuron-methyl (600g/kg) + Glyphosate (360g/L)	0.06g/L + 0.72g/L water + wetter	Foliar
		Triclopyr + Picloram	Triclopyr (300 g/L) + Picloram (100 g/L)	1.5g/L + 0.5g/L water + wetter	Foliar
		Triclopyr + Picloram + Aminopyralid	Triclopyr (300g/L) + Picloram (100g/L) + Aminopyralid (8g/L)	1.5g/L + 0.5g/L + 0.04g/L water + wetter	Foliar
Bryophyllum proliferum Bowie ex Hook.	Crassulaceae	Fluroxypyr	Fluroxypyr (333g/L)	1.2g/L water + wetter	Foliar
		Metsulfuron-methyl	Metsulfuron-methyl (600g/kg)	0.12g/L water + wetter	Foliar
Crassula sarmentosa Harv.	Crassulaceae	Carfentrazone-ethyl + MCPA	Carfentrazone-ethyl (240g/L) + MCPA (500g/L)	0.02g + 0.21g/L water	Foliar

Species	Family	Active constituent	Active constituent with concentration	A.I. (grams) per Litre	Method of Application
		Glufosinate ammonium	Glufosinate ammonium (200g/L)	0.25g/L water	Foliar
Kalanchoe beharensis Drake	Crassulaceae	Fluroxypyr	Fluroxypyr (333g/L)	1.2g/L water + wetter	Foliar
		Metsulfuron-methyl	Metsulfuron-methyl (600g/kg)	0.12g/L water + wetter	Foliar
		Metsulfuron-methyl + Glyphosate	Metsulfuron-methyl (600g/kg) + Glyphosate (360g/L)	0.06g/L + 0.72g/L water + wetter	Foliar
Jatropha gossypiifolia L.	Euphorbiaceae	Fluroxypyr	Fluroxypyr (333g/L)	1.0 g/L water	Foliar
		Fluroxypyr	Fluroxypyr (333g/L)	1.0 g/L water	Foliar
		Glyphosate	Glyphosate (360g/L)	3.6 g/L water	Foliar
		Glyphosate	Glyphosate (360g/L)	3.6 g/L water	Foliar
		Metsulfuron-methyl	Metsulfuron-methyl (600g/kg)	0.09 g/L water + wetter	Foliar
		Metsulfuron-methyl	Metsulfuron-methyl (600g/kg)	0.09 g/L water + wetter	Foliar
		Metsulfuron-methyl + Aminopyralid	Metsulfuron-methyl (300g/kg) + Aminopyralid (375g/L)	0.06g + 0.075g/L water + wetter	Foliar
		Metsulfuron-methyl + Aminopyralid	Metsulfuron-methyl (300g/kg) + Aminopyralid (375g/L)	0.06g + 0.075g/L water + wetter	Foliar
		Triclopyr + Picloram + Aminopyralid	Triclopyr (300g/L) + Picloram (100g/L) + Aminopyralid (8g/L)	1.05g + 0.35g + 0.028g/L water + wetter	Foliar
		Triclopyr + Picloram + Aminopyralid	Triclopyr (300g/L) + Picloram (100g/L) + Aminopyralid (8g/L)	1.05g + 0.35g + 0.028g/L water + wetter	Foliar
Acacia mearnsii De Wild.	Fabaceae	Aminopyralid + Fluroxypyr	Aminopyralid (10g/L) + Fluroxypyr (140g/L)	.07g/L + 0.98g/L water + wetter	Foliar
		Fluroxypyr	Fluroxypyr (333g/L)	2.0g/L water + wetter	Foliar
		Triclopyr	Triclopyr (600g/L)	10g/L diesel	Basal bark/Cut stump
		Triclopyr + Picloram	Triclopyr (240g/L) + Picloram (120g/L)	4g + 2g/L diesel	Basal bark/Cut stump
Acacia melanoxylon R. Br.	Fabaceae	Aminopyralid + Fluroxypyr	Aminopyralid (10g/L) + Fluroxypyr (140g/L)	.07g/L + 0.98g/L water + wetter	Foliar
		Fluroxypyr	Fluroxypyr (333g/L)	2.0g/L water + wetter	Foliar
		Picloram + Aminopyralid	Picloram (43g/Kg) + Aminopyralid (4.3g/Kg)	Neat - 3 to 5 mm layer	Cut stump
		Triclopyr	Triclopyr (600g/L)	10g/L diesel	Basal bark/Cut stump
		Triclopyr + Picloram	Triclopyr (240g/L) + Picloram (120g/L)	4g+2g/L diesel	Basal bark/Cut stump
Caesalpinia decapetala (Roth) Alston	Fabaceae	Aminopyralid + Metsulfuron	Aminopyralid (375g/kg) + Metsulfuron (300g/kg)	0.075g + 0.06g/L water + wetter	Foliar
		Metsulfuron-methyl	Metsulfuron-methyl (600g/kg)	0.06g /L water + wetter	Foliar
		Metsulfuron-methyl + Aminopyralid	Metsulfuron-methyl (300g/kg) + Aminopyralid (375g/L)	0.06g + 0.075g/L water + wetter	Foliar
		Picloram + Aminopyralid	Picloram (43g/Kg) + Aminopyralid (4.3g/Kg)	Neat - 3 to 5 mm layer	Cut stump
		Triclopyr + Metsulfuron	Triclopyr (75g/L) + Metsulfuron (28g/L)	0.19g + 0.07g/L water + wetter	Foliar

Species	Family	Active constituent	Active constituent with concentration	A.I. (grams) per Litre	Method of Application
Parkinsonia aculeata L.	Fabaceae	Hexazinone	Hexazinone (250g/L)	1.0g per spot per tree applied to the soil for trees > 1m tall	Spot ground application
		Hexazinone	Hexazinone (250g/L)	0.25g per spot per tree applied to the soil for trees up to 1m tall	Spot ground application
		Tebuthiuron	Tebuthiuron (200g/L)	0.3g per meter square of soil around tree	Spot ground application
		Triclopyr + Picloram	Triclopyr (240g/L) + Picloram (120g/L)	4g + 2g/L diesel	Basal bark/Cut stump
		Triclopyr + Picloram	Triclopyr (300 g/L)+ Picloram (100 g/L)	1.0g + 0.35g/L water	Foliar
Prosopis juliflora (Sw.) DC.	Fabaceae	Picloram + Aminopyralid	Picloram (43g/Kg) + Aminopyralid (4.3g/Kg)	Neat - 3 to 5 mm layer	Cut stump
		Triclopyr + Picloram	Triclopyr (240g/L) + Picloram (120g/L)	4g + 2g/L diesel	Basal bark/Cut stump
		Triclopyr + Picloram + Aminopyralid	Triclopyr (300g/L) + Picloram (100g/L) + Aminopyralid (8g/L)	1.05g/L + 0.35g/L + 0.028g/L water + wetter	Foliar
Senna occidentalis (L.) Link	Fabaceae	2,4-D + Picloram	2,4-D (300g/L) + Picloram (75g/L)	0.9g + 0.225g/L water + wetter	Foliar
		2,4-D + Picloram	2,4-D (300g/L) + Picloram (75g/L)	0.9g + 0.225g/L water + wetter	Foliar
		Triclopyr + Picloram + Aminopyralid	Triclopyr (300g/L) + Picloram (100g/L) + Aminopyralid (8g/L)	1.05g/L + 0.35g/L + 0.028g/L water + wetter	Foliar
		Triclopyr + Picloram + Aminopyralid	Triclopyr (300g/L) + Picloram (100g/L) + Aminopyralid (8g/L)	1.05g/L + 0.35g/L + 0.028g/L water + wetter	Foliar
Argemone mexicana L.	Papaveraceae	2,4-D	2,4-D (625g/L)	0.73g/L water	Foliar
		2,4-D + Picloram	2,4-D (300g/L) + Picloram (75g/L)	0.25g + 0.06g/L water	Foliar
		Glyphosate	Glyphosate (360g/L)	0.45g/L water	Foliar
Argemone ochroleuca Sweet	Papaveraceae	See Argemone mexicana			
Eichhornia crassipes (Mart.) Solms	Pontederiaceae	Amitrole + Ammonium Thiocyanate	Amitrole (250g/L) + Ammonium Thiocyanate (220g/L)	0.7g + 0.62g/L water	Foliar
		Glyphosate	Glyphosate (360g/L)	4.68g/L + wetter	Foliar
		Metsulfuron-methyl	Metsulfuron-methyl (600g/kg)	0.06g/L water	Foliar
Salvinia molesta D.S. Mitch.	Salviniaceae	Diquat	Diquat (200g/L)	1.67g/L water	Foliar
		Flumioxazin	Flumioxazin (500g/L)	0.35g/L water	Foliar
		Metsulfuron-methyl	Metsulfuron-methyl (600g/kg)	0.06g/L water + wetter	Foliar
Cestrum aurantiacum Lindl.	Solanaceae	Glyphosate	Glyphosate (360g/L)	360g/L water	Cut stump
		Glyphosate	Glyphosate (360g/L)	360g/L water	Stem scrape
		Picloram + Aminopyralid	Picloram (43g/Kg) + Aminopyralid (4.3g/Kg)	Neat - 3 to 5 mm layer	Cut stump
		Triclopyr + Picloram	Triclopyr (240g/L) + Picloram (120g/L)	4g + 2g/L diesel	Basal bark/Cut stump
		Triclopyr + Picloram + Aminopyralid	Triclopyr (300g/L) + Picloram (100g/L) + Aminopyralid (8g/L)	1.2g + 0.4g + 0.032/L water	Foliar

Species	Family	Active constituent	Active constituent with concentration	A.I. (grams) per Litre	Method of Application
Datura stramonium L.	Solanaceae	2,4-D	2,4-D Amine (625g/L)	0.58g/L water	Foliar
		Glyphosate	Glyphosate (360g/L)	2.7g/L water	Foliar
Nicotiana glauca Graham	Solanaceae	2,4-D + Picloram	2,4-D (300g/L) + Picloram (75g/L)	1.95g + 0.49g/L water + wetter	Foliar
		Glyphosate	Glyphosate (360g/L)	7.2g/L water + wetter	Foliar
		Imazapyr	Imazapyr (250g/L)	2.5g/L water	Foliar
		Imazapyr	Imazapyr (250g/L)	50.0g/L water	Cut stump
		Picloram + Aminopyralid	Picloram (43g/Kg) + Aminopyralid (4.3g/Kg)	Neat - 3 to 5 mm layer	Cut stump
		Triclopyr + Picloram	Triclopyr (240g/L) + Picloram (120g/L)	4g + 2g/L diesel	Basal bark/Cut stump
		Triclopyr + Picloram + Aminopyralid	Triclopyr (300g/L) + Picloram (100g/L) + Aminopyralid (8g/L)	1.5g + 0.5g + 0.04g/L water	Foliar
Solanum mauritianum Scop.	Solanaceae	2,4-D + Picloram	2,4-D (300g/L) + Picloram (75g/L)	1.95g + 0.49g/L water + wetter	Foliar
		Glyphosate	Glyphosate (360g/L)	7.2g/L water + wetter	Foliar
		Imazapyr	Imazapyr (250g/L)	2.5g/L water	Foliar
		Imazapyr	Imazapyr (250g/L)	50.0g/L water	Cut stump
		Picloram + Aminopyralid	Picloram (43g/Kg) + Aminopyralid (4.3g/Kg)	Neat - 3 to 5 mm layer	Cut stump
		Triclopyr + Picloram	Triclopyr (240g/L) + Picloram (120g/L)	4g + 2g/L diesel	Basal bark/Cut stump
		Triclopyr + Picloram + Aminopyralid	Triclopyr (300g/L) + Picloram (100g/L) + Aminopyralid (8g/L)	1.5g + 0.5g + 0.04g/L water	Foliar
Lantana camara L.	Verbenaceae	2,4-D + Picloram	2,4-D (300g/L) + Picloram (75g/L)	1.95g/L + 0.49g/L water + wetter	Foliar
		Aminopyralid + Fluroxypyr	Aminopyralid (10g/L) + Fluroxypyr (140g/L)	.07g/L + 0.98g/L water + wetter	Foliar
		Aminopyralid + Fluroxypyr	Aminopyralid (10g/L) + Fluroxypyr (140g/L)	1.0g/L + 14.0g/L water + wetter	Splatter gun
		Fluroxypyr	Fluroxypyr (200g/L)	2.0g/L water + wetter	Foliar
		Glyphosate	Glyphosate (360g/L)	3.6g/L water + wetter	Foliar
		Glyphosate	Glyphosate (360g/L)	36g/L water + wetter	Splatter gun
		Metsulfuron-methyl	Metsulfuron-methyl (600g/kg)	1.2g/L water + wetter	Splatter gun
		Picloram + Aminopyralid	Picloram (43g/Kg) + Aminopyralid (4.3g/Kg)	Neat - 3 to 5 mm layer	Cut stump
		Triclopyr	Triclopyr (600g/L)	10g/L diesel	Basal bark/Cut stump
		Triclopyr + Picloram	Triclopyr (240g/L) + Picloram (120g/L)	4g +2g/L diesel	Basal bark/Cut stump
		Triclopyr + Picloram + Aminopyralid	Triclopyr (300g/L) + Picloram (100g/L) + Aminopyralid (8g/L)	2.25g + 0.75g + 0.06g/L water + wetter	Foliar
Verbena bonariensis L.	Verbenaceae	2,4-D	2,4-D Amine (625g/L)	1.8 g/L water	Foliar
		Imazapyr	Imazapyr (250g/L)	2.0 g/L water	Foliar
		MCPA	MCPA (500g/L)	2.35 g/L water	Foliar

Appendix D

Registered and minor-use* herbicides applied in South Africa for the control of some of the plant species included in this Field Guide with herbicide concentrations/volumes based on weed densities of closed stands (100% cover) [South Africa Department of Environment Affairs (DEA): Environmental Programmes (EP): Natural Resource Management (NRM) and XACT Information (2005)]. Please note that "lopping/pruning" and "cut and spray" applications use a similar methodology as that of "cut-stump," as explained elsewhere.

(Abbreviations used: cm = centimetre; EC = emulsifiable concentrate0; g/kg = grams per kilogram; g/l = grams per litre; ha = hectare; kg = kilogram; l = litre; m = metre; m2 = square metre; ME = micro-emulsion; ml = millilitre; mm = millimetre; SC = suspension concentrate; SL = solution; WG = water dispensable granule; WP = wettable powder)

Species	Active constituent with concentration	Age	Dosage (ml/g)	Wetter/ dye	A.I, (L/kg)	Mix (L)	% mix	Estimated product (L/ha or kg/ha)	Vol. of mix	Method of application
Agave americana L. (Agavaceae)	MSMA 720 g/L SL	All ages	10000		10	10	100	50	50	Stem inject
	Glyphosate (as sodium salt) 500g/kg WG	Young	200		0.2	10	2	6	300	Foliar spray
	Glyphosate (as isopropylamine salt) 480 g/L SL	Young	200		0.2	10	2	6	300	Foliar spray
Agave sisalana perinne (Agavaceae)	MSMA 720 g/L SL	All ages	10000		10	10	100	50	50	Stem inject
			Use 2 ml concentrate per plant and inject into the sisal bole. Burn after plants have died and leaves have dried out.							
	Glyphosate (as sodium salt) 500g/kg WG	Young	200		0.2	10	2	6	300	Foliar spray
	Glyphosate (as isopropylamine salt) 480 g/L SL	Young	200		0.2	10	2	6	300	Foliar spray
Ageratum conyzoides L. (Asteraceae)	2.4D (as dimeth-ylamine salt) 480g/L SL	Young	150	0.10%	0.15	10	1.5	2.25	150	Foliar spray
	Glyphosate (as isopropylamine salt) 480 g/L SL		150		0.15	10	1.5	4.5	300	Foliar spray
			Use 100 ml/10 l water. Apply as a full cover spray.							
Cirsium vulgare (Savi) Ten. (Asteraceae)	Clopyralid 90 + Triclopyr (as amine salt) 270 g/L SL	Young	75	0.50%	0.075	10	0.75	2.25	300	Foliar spray
	Fluroxypyr 80 + Picloram 80 g/L ME		75	0.50%	0.075	10	0.75	2.25	300	Foliar spray
	Picloram (as potassium salt) 240g/L SL		50	0.50%	0.05	10	0.5	1.5	300	Foliar spray

Species	Active constituent with concentration	Age	Dosage (ml/g)	Wetter/ dye	A.I, (L/kg)	Mix (L)	% mix	Estimated product (L/ha or kg/ha)	Vol. of mix	Method of application
Parthenium hysterophorus L. (Asteraceae)	Glyphosate (as potassium salt) 500 SL	Young	200	0.10%	0.2	10	2	6	300	Foliar spray
	Picloram (as potassium salt) 240g/L SL		50	0.50%	0.05	10	0.5	1.5	300	Foliar spray
	Glyphosate (as isopropylamine salt) 480 g/L SL		150		0.15	10	1.5	4.5	300	Foliar spray
Xanthium strumarium L. (Asteraceae)	2.4D (as dimethylamine salt) 480g/L SL	Young	150	0.10%	0.15	10	1.5	2.25	150	Foliar spray
	Chlorimuron ethyl (as sulfonyl urea) 500g/kg WP		17.5	0.10%	0.0175	10	0.175	0.525	300	Foliar spray
Cereus jamacaru DC. (Cactaceae)	MSMA 720 g/L SL	All ages	10000		10	10	100	50	50	Stem inject
			Use1 l/2 l water. Apply one injection/stem shorter than 2.5 m and two injections/stem higher than 2.5 m into pre-made holes (2 ml per hole).							
Opuntia engelmannii Salm-Dyck ex Engelmann. (Cactaceae)	Glyphosate (as isopropylamine salt) 360 g/L SL*	Adult	4800		4.8	10	48	24	50	Stem inject
Opuntia ficus-indica (L.) Mill. (Cactaceae)	Glyphosate (as ammonium salt) 680 g/kg WG	All	1800	0.10%	1.8	10	18	9	50	Stem inject
			Use 1.8 kg/10 l water. Inject 2 ml in pre-made holes in the stem of the plant (4 – 12 pre-made holes for plants with 20 – 250 cladodes).							
	Glyphosate (as isopropylamine salt) 360 g/L SL		3300	0.10%	3.3	10	33	16.5	50	Stem inject
	Glyphosate (as potassium salt) 450g/L SL		1800	0.10%	1.8	10	18	9	50	Stem inject
	Glyphosate (as potassium salt) 500 SL		2200	0.10%	2.2	10	22	11	50	Stem inject
			Use 2.2 l/10 l water. For plants with 20 – 250 cladodes drill 4 – 12 holes in stem and inject 3 ml/hole							
Opuntia microdasys (Lehm.) Pfeiff (Cactaceae)	Glyphosate (as isopropylamine salt) 360 g/L SL*	Adult	4800		4.8	10	48	24	50	Stem inject
Acacia mearnsii De Wild. (Fabaceae)	Clopyralid 90 + Triclopyr (as amine salt) 270 g/L SL	Seedling	40	0.50%	0.04	10	0.4	1.2	300	Foliar spray
			Use 30-50 ml + 50 ml mineral oil/10 ml water. Apply the lower rate on seedlings and the higher rate on saplings as a full cover spray.							
	Fluroxypyr 200 g/L EC		12.5	0.50%	0.0125	10	0.125	0.375	300	Foliar spray

Species	Active constituent with concentration	Age	Dosage (ml/g)	Wetter/ dye	A.I, (L/kg)	Mix (L)	% mix	Estimated product (L/ha or kg/ha)	Vol. of mix	Method of application
		Seed-ling	Use 12.5 ml + 50 ml of mineral oil/ 10 l water. Apply as a full cover spray on young, actively growing plants up to 1 m high.							
	Glyphosate (as ammonium salt) 680 g/kg WG		80	0.50%	0.08	10	0.8	2.4	300	Foliar spray
			Use 80 g/10 l water. Apply to plants up to 1 m high.							
	Glyphosate (as isopropylamine salt) 360 g/L SL		150	0.10%	0.15	10	1.5	4.5	300	Foliar spray
			Use 150 ml/10 l water. Apply in summer to plants up to 1 m high.							
	Glyphosate (as potassium salt) 450g/L SL		120	0.10%	0.12	10	1.2	3.6	300	Foliar spray
			Use 120 ml/10 l water. Spray plants up to 1 m high.							
	Glyphosate (as isopropylamine salt) 480 g/L SL		110	0.10%	0.11	10	1.1	3.3	300	Foliar spray
			Use 110 ml/10 l of water. Spray plants up to 1 m high.							
	Glyphosate (as sodium salt) 500g/kg WG		110	0.10%	0.11	10	1.1	3.3	300	Foliar spray
			Use 100 g/10 l water to young trees up to 1 m high.							
	Triclopyr (as butoxy ethyl ester) 240 g/L EC		50	0.10%	0.05	10	0.5	1.5	300	Foliar spray
			Use 50-150 ml + 50 ml mineral oil/10 l water. Apply as a full cover spray to actively growing plants. Use lower rate on seedlings (smaller than 50 cm high) and higher rate on seedlings.							
	Triclopyr (as triethyl ammonium) 120 g/L + Aminopyralid 12 g/L		50	0.50%	0.05	10	0.5	1.5	300	Foliar spray
	Triclopyr (as butoxy ethyl ester) 480 g/L EC		25	0.50%	0.025	10	0.25	0.75	300	Foliar spray
			Use 25 – 75 ml+ 50 ml mineral oil/10 l water. Apply as a full cover spray to actively growing plants. Use lower rate on seedlings (smaller than 50 cm high) and higher rate on seedlings.							
	Triclopyr (as butoxy ethyl ester) 240 g/L + Aminopyralid 30 g/L		25	0.50%	0.025	10	0.25	0.75	300	Foliar spray
	Clopyralid 90 + Triclopyr (as amine salt) 270 g/L SL		50	0.50%	0.05	10	0.5	1.5	300	Foliar spray
	Fluroxypyr 80 + Picloram 80 g/L ME		75	0.50%	0.075	10	0.75	2.25	300	Foliar spray
			Use 75 ml + 50 ml mineral oil/10 l water. Apply as a full cover spray on actively growing plants.							

Species	Active constituent with concentration	Age	Dosage (ml/g)	Wetter/ dye	A.I, (L/kg)	Mix (L)	% mix	Estimated product (L/ha or kg/ha)	Vol. of mix	Method of application
	Glyphosate (as potassium salt) 500 SL	Seed-ling	100	0.10%	0.1	10	1	3	300	Foliar spray
			Use 100 ml/10 l water. Apply in summer to young trees 1-2 m high.							
	Triclopyr (as butoxy ethyl ester) 240 g/L EC		150	0.10%	0.15	10	1.5	4.5	300	Foliar spray
	Triclopyr (as butoxy ethyl ester) 480 g/L EC		75	0.10%	0.075	10	0.75	2.25	300	Foliar spray
	Fluroxypyr 80 + Picloram 80 g/L ME	Young	200	0.50%	0.2	10	2	4	200	Lopping/ pruning
	Imazapyr 100 g/L SL		1000		1	10	10	20	200	Lopping/ pruning
	Picloram (as potassium salt) 240g/L SL		150	0.50%	0.15	10	1.5	3	200	Lopping/ pruning
	Triclopyr (as amine salt) 360 g/L SL		300	0.50%	0.3	10	3	6	200	Lopping/ pruning
	Triclopyr (as triethyl ammo-nium) 120 g/L + Aminopyralid 12 g/L		200	0.50%	0.2	10	2	4	200	Lopping/ pruning
	Fluroxypyr 80 + Picloram 80 g/L ME	Adult	200	0.50%	0.2	10	2	4	200	Cut stump/ frill
	Imazapyr 100 g/L SL		1000		1	10	10	20	200	Cut stump/ frill
			Use 1 l/10 l of water. Apply to freshly cut stumps. Apply at least 10 ml per 100 mm of stump diameter.							
	Picloram (as potassium salt) 240g/L SL		150	0.50%	0.15	10	1.5	3	200	Cut stump/ frill
			Use 600 ml + 200 ml mineral oil/10 ml water. Apply sufficient mixture to fill the frill.							
	Triclopyr (as amine salt) 360 g/L SL		300	0.50%	0.3	10	3	6	200	Cut stump/ frill
			Use 300 ml + 50 ml mineral oil/10 l water. Apply to the cut surface of low cut stumps.							
	Triclopyr (as triethyl ammo-nium) 120 g/L + Aminopyralid 12 g/L		200	0.50%	0.2	10	2	4	200	Cut stump/ frill
			1 sachet / 400ml sunflower oil					200		Cut stump/ frill
	Picloram (as potassium salt) 240g/L SL		600	2.00%	0.6	10	6	12	200	Frill
			Use 150 ml + 50 ml mineral oil/10 l water. Apply to the cut surface of low cut stumps within 3 hours of felling.							

Species	Active constituent with concentration	Age	Dosage (ml/g)	Wetter/ dye	A.I, (L/kg)	Mix (L)	% mix	Estimated product (L/ha or kg/ha)	Vol. of mix	Method of application
	Triclopyr (as butoxy ethyl ester) 480 g/L EC	Adult	200		0.2	10	2	4	200	Basal bark + diesel
			Use 200 ml/10 l of diesel for plants with a stem diameter of up to 10 cm. Ensure wetting of the root crown, exposed roots and stem up to a height of 25 cm.							
Acacia melanoxylon R.Br. (Fabaceae)	Clopyralid 90 + Triclopyr (as amine salt) 270 g/L SL	Seedling	70	0.50%	0.07	10	0.7	2.1	300	Foliar spray
			Use 70 ml + 50 ml mineral oil/10 l water. Apply to young actively growing saplings up to 2 m high.							
	Fluroxypyr 200 g/L EC		12.5	0.10%	0.0125	10	0.125	0.375	300	Foliar spray
			Use 12.5 ml + 50 ml mineral oil/10 l water. Apply as a full cover spray to young actively growing plants up to 1 m high.							
	Triclopyr (as butoxy ethyl ester) 480 g/L EC		75	0.50%	0.075	10	0.75	2.25	300	Foliar spray
			Use 75 ml + 50 ml mineral oil/10 l water. Apply to young actively growing plants up to 2 m high.							
	Triclopyr (as triethyl ammonium) 120 g/L + Aminopyralid 12 g/L		100	0.50%	0.1	10	1	3	300	Foliar spray
	Triclopyr (as butoxy ethyl ester) 240 g/L + Aminopyralid 30 g/L		50	0.50%	0.05	10	0.5	1.5	300	Foliar spray
			Use 150 ml + 50 ml mineral oil/10 l water. Apply as a full cover spray to young actively growing trees up to 2 m high.							
	Clopyralid 90 + Triclopyr (as amine salt) 270 g/L SL	Young	400	0.50%	0.4	10	4	8	200	Lopping/ pruning
	Triclopyr (as amine salt) 360 g/L SL		600	0.50%	0.6	10	6	12	200	Lopping/ pruning
	Triclopyr (as triethyl ammonium) 120 g/L + Aminopyralid 12 g/L		400	0.50%	0.4	10	4	8	200	Lopping/ pruning
	Clopyralid 90 + Triclopyr (as amine salt) 270 g/L SL	Adult	400	0.50%	0.4	10	4	8	200	Cut stump/ frill
			Use 400 ml + 50 ml mineral oil/10 l water. Apply to cut surface of low cut stumps within 3 hours of felling.							
	Triclopyr (as amine salt) 360 g/L SL		600	0.50%	0.6	10	6	12	200	Cut stump/ frill
			Use 600 ml + 50 ml mineral oil/10 l water. Apply to cut surface of low cut stumps within 3 hours of felling.							

Species	Active constituent with concentration	Age	Dosage (ml/g)	Wetter/ dye	A.I, (L/kg)	Mix (L)	% mix	Estimated product (L/ha or kg/ha)	Vol. of mix	Method of application
	Triclopyr (as triethyl ammonium) 120 g/L + Aminopyralid 12 g/L	Adult	400	0.50%	0.4	10	4	8	200	Cut stump/ frill
	Triclopyr (as butoxy ethyl ester) 480 g/L EC		200		0.2	10	2	4	200	Basal bark + diesel
			Use 200 ml/10 l diesel for plants with a stem diameter of up to 10 cm. Ensure wetting of the root crown, exposed roots and stem up to a height of 25 cm.							
Caesalpinia decapetala (Roth) Alston (Fabaceae)	Glyphosate (as ammonium salt) 680 g/kg WG	Young	80	0.10%	0.08	10	0.8	2.4	300	Foliar spray
			Use 10 g/10 l water. Apply to plants up to 1 m high.							
	Glyphosate (as isopropylamine salt) 360 g/L SL		150	0.10%	0.15	10	1.5	4.5	300	Foliar spray
			Use 150 ml/10 l water. Apply to plants up to 1 m high.							
	Glyphosate (as potassium salt) 450g/L SL		120	0.10%	0.12	10	1.2	3.6	300	Foliar spray
	Glyphosate (as isopropylamine salt) 480 g/L SL		110	0.10%	0.11	10	1.1	3.3	300	Foliar spray
			Use 110 ml/10 l water. Apply to plants up to 1 m high.							
	Glyphosate (as potassium salt) 500 SL		100	0.10%	0.1	10	1	3	300	Foliar spray
			Use 100 ml/10 l water. Apply in summer.							
	Glyphosate (as sodium salt) 500g/kg WG		110	0.50%	0.11	10	1.1	3.3	300	Foliar spray
	Triclopyr (as butoxy ethyl ester) 240 g/L EC		100	0.10%	0.1	10	1	3	300	Foliar spray
			Use 100 ml + 50 ml mineral oil/10 l water. Apply as a full cover spray to actively growing plants up to 3 m high. Taller plants must be cut back and regrowth treated.							
	Triclopyr (as butoxy ethyl ester) 480 g/L EC		50	0.50%	0.05	10	0.5	1.5	300	Foliar spray
			Use 50 ml + 50 ml mineral oil/10 l water. Apply as a full cover spray to actively growing plants up to 3 m high. Taller plants must be cut back and regrowth treated.							
	Triclopyr (as amine salt) 360 g/L SL	Adult	300	0.10%	0.3	10	3	6	200	Cut and spray
Prosopis glandulosa Torr. (Fabaceae)**	Clopyralid 90 + Triclopyr (as amine salt) 270 g/L SL	Seedling	150	0.50%	0.15	10	1.5	4.5	300	Foliar spray
			Use 100-150 ml + 50 ml mineral oil/10 l water. Apply as a full cover spray. Plants to high should be slashed and regrowth sprayed.							

Species	Active constituent with concentration	Age	Dosage (ml/g)	Wetter/ dye	A.I, (L/kg)	Mix (L)	% mix	Estimated product (L/ha or kg/ha)	Vol. of mix	Method of application
	Glyphosate (as potassium salt) 500 SL	Seed-ling	500	0.10%	0.5	10	5	15	300	Foliar spray
			Use 350-660 ml/10 l water. Apply to seedlings and regrowth.							
	Triclopyr (as triethyl ammo-nium) 120 g/L + Aminopyralid 12 g/L		300	0.50%	0.3	10	3	9	300	Foliar spray
	Clopyralid 90 + Triclopyr (as amine salt) 270 g/L SL	Young	400	0.50%	0.4	10	4	8	200	Lopping/ pruning
	Triclopyr (as bu-toxy ethyl ester) 240 g/L EC		800	0.10%	0.8	10	8	16	200	Lopping/ pruning
	Triclopyr (as amine salt) 360 g/L SL		500	2.00%	0.5	10	5	10	200	Lopping/ pruning
	Clopyralid 90 + Triclopyr (as amine salt) 270 g/L SL	Adult	400	0.50%	0.4	10	4	8	200	Cut stump/ frill
			Use 400 ml + 50 ml mineral oil/10 l water. Apply to cut surface of low cut stumps within 3 hours of felling,							
	Triclopyr (as butoxy ethyl ester) 240 g/L EC		800	0.10%	0.8	10	8	16	200	Cut stump/ frill
			Use 800 ml/10 l diesel. Apply to the cut surface and all bark and root crown of low cut stumps.							
	Triclopyr (as amine salt) 360 g/L SL		500	2.00%	0.5	10	5	10	200	Cut stump/ frill
			Use 500 ml + 200 ml mineral oil/10 l water. Apply to the cut sur-face of low cut stumps within three hours of felling.							
	Picloram (as potassium salt) 54g/kg + Triclopyr (as triethylamine) 36g/kg		Paint directly on to stumps 10g/10mm stump			200				
	Triclopyr (as bu-toxy ethyl ester) 480 g/L EC		400	0.50%	0.4	10	4	8	200	Cut stump/ frill
	Glyphosate (as potassium salt) 500 SL	All	500	0.50%	0.5	10	5	20	400	Aerial application
Senna occidentalis (L.) Link (Fabaceae)	Imazapyr 100 g/L SL*	Adult	500		0.5	10	5	10	200	Cut and spray
Argemone mexicana L. (Papa-veraceae)	Glyphosate (as isopropylamine salt) 180 g/l SL	Young	150		0.15	10	1.5	6	400	Foliar spray
	Glyphosate (as sodium salt) 500g/kg WG		220		0.22	10	2.2	8.8	400	Foliar spray

Species	Active constituent with concentration	Age	Dosage (ml/g)	Wetter/ dye	A.I, (L/kg)	Mix (L)	% mix	Estimated product (L/ha or kg/ha)	Vol. of mix	Method of application
	Tebuthiuron 250g/L + Bromacil 250g/L SC	All	600		0.6	10	6	90	1500	Soil
Argemone ochroleuca Sweet (Papaveraceae)	Glyphosate (as isopropylamine salt) 180 g/l SL	Young	150		0.15	10	1.5	6	400	Foliar spray
	Glyphosate (as sodium salt) 500g/kg WG		220		0.22	10	2.2	8.8	400	Foliar spray
	Tebuthiuron 250g/L + Bromacil 250g/L SC*	All	600		0.6	10	6	90	1500	Soil
Eichhornia crassipes (C. Mart) Solms (Pontederiaceae)	Glyphosate (as sodium salt) 700g/kg WG	All	220	0.50%	0.22	10	2.2	6.6	300	Spray from boat/ shoreline
	Glyphosate (as isopropylamine salt) 480 g/L SL		220	0.10%	0.22	10	2.2	6.6	300	Spray from boat/ shoreline
			Use 220ml/10 l water with a pressurized or knapsack sprayer and 300 ml/10 l with a mistblower. Apply when maximum exposure of leaves is visible.							
	Glyphosate (as sodium salt) 500g/kg WG		220		0.22	10	2.2	6.6	300	Spray from boat/ shoreline
	Glyphosate (as potassium salt) 500 SL		450		0.45	10	4.5	13.5	300	Spray from boat/ shoreline
			Use 200-265 ml/10 l water. Apply in summer on actively growing plants.							
	Glyphosate (as phosponic acid) 480g/L SL		225		0.225	10	2.25	6.75	300	Spray from boat/ shoreline
	Diquat dibromide (as dibromide salt) 200g/L SL		500		0.5	10	5	2.5	50	Aerial
			Use 7.5-10 l + 1.5 l wetting agent – 40 l water/ha. Apply on actively growing plants.							
	Glyphosate (as potassium salt) 500 SL		450		0.45	10	4.5	4.5	100	Aerial
			Use 4-5.3 l/30 l water/ha. Apply in summer on actively growing plants.							
Salvinia molesta D.S. Mitch. (Salviniaceae)	Glyphosate (as sodium salt) 500g/kg WG	All	300	0.10%	0.3	10	3	9	300	Spray from boat/ shoreline
	Glyphosate (as sodium salt) 700g/kg WG		300	0.10%	0.3	10	3	9	300	Spray from boat/ shoreline
	Glyphosate (as isopropylamine salt) 480 g/L SL		200	0.10%	0.2	10	2	6	300	Spray from boat/ shoreline

Species	Active constituent with concentration	Age	Dosage (ml/g)	Wetter/ dye	A.I, (L/kg)	Mix (L)	% mix	Estimated product (L/ha or kg/ha)	Vol. of mix	Method of application
	Diquat dibromide (as dibromide salt) 200g/L SL	All	500	0.10%	0.5	10	5	2.5	50	Aerial
			Use 7.5 – 10 l + 1.5 l Agral 90/ha. Apply in 35 – 40 l water/ha.							
Cestrum aurantiacum Lindl. (Solanaceae)	Imazapyr 100 g/L SL	Adult	150		0.15	10	1.5	3	200	Cut and spray
Datura stramonium L. (Solanaceae)	2.4D (as dimethylamine salt) 480g/L SL	Young	150	0.10%	0.15	10	1.5	2.25	150	Foliar spray
	Chlorimuron ethyl (as sulfonyl urea) 500g/kg WP		17.5	0.10%	0.0175	10	0.175	0.35	200	Foliar spray
	Glyphosate (as sodium salt) 500g/kg WG		110		0.11	10	1.1	2.2	200	Foliar spray
	Glyphosate (as isopropylamine salt) 180 g/l SL		150		0.15	10	1.5	3	200	Foliar spray
	Tebuthiuron 250g/L + Bromacil 250g/L SC	All	150		0.15	10	1.5	3	200	Soil
Nicotiana glauca R. Graham (Solanaceae)	Glyphosate (as isopropylamine salt) 360 g/L SL*	Young	300	0.10%	0.3	10	3	12	400	Foliar spray
Solanum mauritianum Scop. (Solanaceae)	Glyphosate (as isopropylamine salt) 360 g/L SL		50	0.50%	0.05	10	0.5	1.5	300	Foliar spray
			Use 150 ml/10 l water. Slash tall plants and apply when regrowth is 1 m high. Use 50 ml/10 l water on saplings less than 1 m high.							
	Clopyralid 90 + Triclopyr (as amine salt) 270 g/L SL		600	0.50%	0.6	10	6	18	300	Foliar spray
			Use 600 ml + 50 ml mineral oil/100 l water. Apply to actively growing plants. Plants too high for good coverage should be slashed and the regrowth sprayed when 0.5 m high.							
	Fluroxypyr 200 g/L EC	Young	12.5	0.50%	0.0125	10	0.125	0.375	300	Foliar spray
			Use 12.5 ml + 50 ml mineral oil/10 l water on young actively growing plants up to 1 m high.							
	Fluroxypyr 80 + Picloram 80 g/L ME		25	0.50%	0.025	10	0.25	0.75	300	Foliar spray
			Use 25 ml + 50 ml mineral oil10 l water. Apply as a full cover spray on actively growing plants.							
	Glyphosate (as ammonium salt) 680 g/kg WG		80	0.10%	0.08	10	0.8	2.4	300	Foliar spray
			Use 80 g/10 l water for seedlings up to 1 m high. Slash tall plants and spray regrowth at 0.5 m high.							

Species	Active constituent with concentration	Age	Dosage (ml/g)	Wetter/ dye	A.I, (L/kg)	Mix (L)	% mix	Estimated product (L/ha or kg/ha)	Vol. of mix	Method of application
	Glyphosate (as isopropylamine salt) 360 g/L SL		150	0.10%	0.15	10	1.5	4.5	300	Foliar spray
			Use 150 ml/10 l water. Slash tall plants and apply when regrowth is 1 m high. Use 50 ml/10 l water on saplings less than 1 m high.							
	Glyphosate (as potassium salt) 450g/L SL		40	0.10%	0.04	10	0.4	1.2	300	Foliar spray
	Glyphosate (as isopropylamine salt) 480 g/L SL		40	0.10%	0.04	10	0.4	1.2	300	Foliar spray
			Use 40 ml/10 l water. Spray seedling up to 1m high.							
	Glyphosate (as potassium salt) 500 SL		100	0.10%	0.1	10	1	3	300	Foliar spray
			Use 100 ml/10 l water. Apply to sapling in spring or summer. Cut large trees and apply when regrowth is more than 500 mm.							
	Glyphosate (as sodium salt) 500g/kg WG		36	0.10%	0.036	10	0.36	1.08	300	Foliar spray
	Glyphosate (as sodium salt) 700g/kg WG	Young	103		0.103	10	1.03	3.09	300	Foliar spray
	Imazapyr 100 g/L SL		63	0.10%	0.063	10	0.63	1.89	300	Foliar spray
			Use 63 ml per 10 l water. Apply as a full cover spray to regrowth 0.5 to 1.0 m high.							
	Triclopyr (as butoxy ethyl ester) 240 g/L EC		100	0.10%	0.1	10	1	3	300	Foliar spray
			Use 100 ml + 50 ml mineral oil /10 l water. Apply to young actively growing plants. Plants higher than 1.5 m should be slashed and regrowth treated when 0.5 m high.							
	Triclopyr (as butoxy ethyl ester) 480 g/L EC		50	0.10%	0.05	10	0.5	1.5	300	Foliar spray
			Use 50 ml + 50 ml mineral oill/10 l water. Apply to young actively growing plants. Plants higher than 1.5 m should be slashed and regrowth treated when 0.5 m high.							
	Triclopyr (as butoxy ethyl ester) 240 g/L + Aminopyralid 30 g/L		37.5	0.50%	0.0375	10	0.375	1.125	300	Foliar spray
	Glyphosate (as ammonium salt) 680 g/kg WG in plastic capsules		265	0.10%	0.265	10	2.65	7.95	300	Cut and spray
		Adult	Cut trees 10 cm above ground level and knock Ecoplugs with a hammer into punched or drilled holes (28 – 35 mm deep) in the stem and exposed roots. Number of plugs depends on stump diameter.							
	Picloram (as potassium salt) 54g/kg + Triclopyr (as triethylamine) 36g/kg		Paint directly on to stumps 10g/10mm stump					200		Cut and spray

Species	Active constituent with concentration	Age	Dosage (ml/g)	Wetter/ dye	A.I, (L/kg)	Mix (L)	% mix	Estimated product (L/ha or kg/ha)	Vol. of mix	Method of application
	Glyphosate (as isopropylamine salt) 480 g/L SL	Adult	110	0.10%	0.11	10	1.1	2.2	200	Cut and spray
			Use 110 ml/10 l water for regrowth of large trees of which the stems have been cut back to a height of 5 – 20 cm.							
	Imazapyr 100 g/L SL		200		0.2	10	2	4	200	Cut and spray
			Use 200 ml/10 l water. Apply to freshly cut stumps. Use at least 10 ml per 10 cm of stump diameter.							
	Picloram (as potassium salt) 240g/L SL		100	0.50%	0.1	10	1	2	200	Cut and spray
			Use 100 ml + 50 ml mineral oil/10 l water. Apply to the cut surface of low cut stumps within three hours of felling.							
	Triclopyr (as amine salt) 360 g/L SL		300	0.50%	0.3	10	3	6	200	Cut and spray
			Use 300 ml + 50 ml mineral oil/10 l water. Apply to the cut surface of low cut stumps within three hours of felling.							
	Glyphosate (as sodium salt) 500g/kg WG		75	0.50%	0.075	10	0.75	1.5	200	Cut and spray
	Triclopyr (as butoxy ethyl ester) 480 g/L EC		2000		2	10	20	40	200	Basal bark + diesel
			Use 200 ml/10 l diesel for plants with a stem diameter up to 10 cm ensure wetting of the root crown, exposed roots and stem up to a height of 25 cm.							
	Fluroxypyr 200 g/L EC		100		0.1	10	1	2	200	Basal bark + diesel
Lantana camara L. (Verbenaceae)	Fluroxypyr 80 + Picloram 80 g/L ME	Young	150	0.50%	0.15	10	1.5	4.5	300	Foliar spray
			Use 150 ml + 50 ml mineral oil/10 l water. Apply as a full cover spray on actively growing plants.							
	Glyphosate (as ammonium salt) 680 g/kg WG		160	0.10%	0.16	10	1.6	4.8	300	Foliar spray
			Use 160 g/10 l water with knapsack sprayer or 200 g/10 l water with mistblower. Apply as a full cover spay.							
	Glyphosate (as isopropylamine salt) 360 g/L SL		300	0.10%	0.3	10	3	9	300	Foliar spray
			Use 300 ml/10 l water with knapsack sprayer or 400 ml/10 l water with mistblower. Apply as a full cover spray in summer to autumn.							
	Glyphosate (as potassium salt) 450g/L SL		240	0.10%	0.24	10	2.4	7.2	300	Foliar spray
	Glyphosate (as isopropylamine salt) 480 g/L SL		220	0.10%	0.22	10	2.2	6.6	300	Foliar spray
			Use 220 ml/10 l water with knapsack sprayer and 300 ml/10 l with a mistblower.							

Species	Active constituent with concentration	Age	Dosage (ml/g)	Wetter/ dye	A.I, (L/kg)	Mix (L)	% mix	Estimated product (L/ha or kg/ha)	Vol. of mix	Method of application
	Glyphosate (as potassium salt) 500 SL		200	0.10%	0.2	10	2	6	300	Foliar spray
			Use 200 ml/10 l water. Slash large bushes in winter and apply to regrowth in summer.							
	Glyphosate (as sodium salt) 500g/kg WG		220	0.50%	0.22	10	2.2	6.6	300	Foliar spray
	Imazapyr 100 g/L SL	Young	200		0.2	10	2	6	300	Foliar spray
			Use 200 ml/10 l water. Apply as a full cover spray when regrowth is 0.5 to 1 m high.							
	Picloram (as potassium salt) 240g/L SL		100	0.50%	0.1	10	1	3	300	Foliar spray
			Use 75–100 ml + 50 ml mineral oil/10 l water. For high volume application use 50 ml/10 l water and add a foaming agent. Apply as a full cover spray. Use higher rate for previously slashed plants with big stumps.							
	Fluroxypyr 80 + Picloram 80 g/L ME		150	0.50%	0.15	10	1.5	3	200	Cut and spray
			Use 150 ml + 50 ml mineral oil/10 l water. Apply to cut surface of low cut stumps within three hours of felling.							
	Imazapyr 100 g/L SL		200		0.2	10	2	4	200	Cut and spray
		Adult	Use 200 ml/10 l water. Apply to the cut surface of freshly cut stumps. Use at least 10 ml per 10 cm of stump diameter.							
	Picloram (as potassium salt) 240g/L SL		100	0.50%	0.1	10	1	2	200	Cut and spray
			Use 100 ml + 50 ml mineral oil/10 l water. Apply to the cut surface of low cut stumps within three hours of felling.							
Verbena bonariensis L. (Verbenaceae)	Glyphosate (as isopropylamine salt) 360 g/L SL		300		0.3	10	3	9	300	Foliar spray
	Metsulfuron methyl 600g/ kg WP	Young	25		0.25	100	0.25	0.75	300	Foliar spray
			Use 2.5 g/10 l water and add a surfactant. Apply to actively growing plants during the later summer.							

** Although *Prosopis glandulosa* is not present in Kenya, herbicides used for its control in South Africa may be effective against *P. juliflora*.

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GUIDE TO THE NATURALIZED AND INVASIVE PLANTS OF

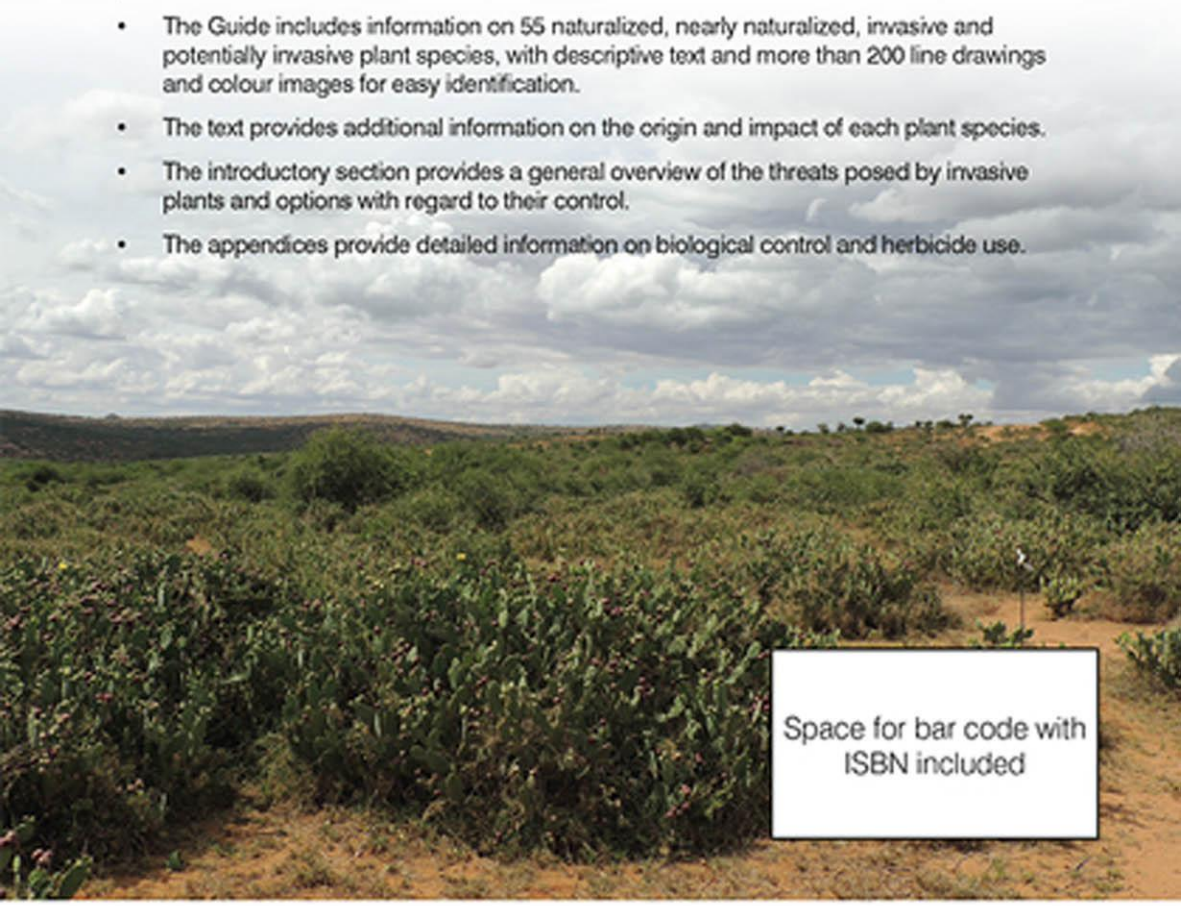
LAIKIPIA COUNTY

Arne Witt, CABI

Laikipia County, known for its abundant wildlife and its pastoralist communities, is a mosaic of grasslands, savannah woodland and forest. This area hosts the highest populations of endangered large mammals in Kenya, including half of the country's rhino population, together with significant populations of elephants, Grévy's zebra, reticulated giraffe, and wild dogs. However, these iconic mammals, and the habitats in which they thrive, are threatened by a host of invasive alien plant species. These invasive plants also threaten the livelihoods of thousands of people dependent on these productive rangelands.

Management of invasive plant species is hampered by the lack of information on their presence, impact, and control. This Field Guide has been developed to help address these very issues. Only those species which we consider to be threatening biodiversity and livestock production have been included.

- The Guide includes information on 55 naturalized, nearly naturalized, invasive and potentially invasive plant species, with descriptive text and more than 200 line drawings and colour images for easy identification.
- The text provides additional information on the origin and impact of each plant species.
- The introductory section provides a general overview of the threats posed by invasive plants and options with regard to their control.
- The appendices provide detailed information on biological control and herbicide use.



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