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RICHNESS AND DIVERSITY OF ALIEN ETHNOMEDICINAL PLANT TAXA USED AND SOLD FOR TRADITIONAL MEDICINE IN SOUTH AFRICA



A dissertation submitted to the Faculty of Science,
University of the Witwatersrand, Johannesburg,
in fulfilment of the requirements for the degree of course work Master of Science

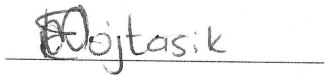
By Ewa Mariola Wojtasik

(September 2013)

Supervisors: Dr Vivienne L. Williams and Prof. Marcus Byrne

DECLARATION

I, Ewa Mariola Wojtasik, hereby declare that this dissertation is my own work. It is being submitted for a course work Masters of Science degree at the University of the Witwatersrand, Johannesburg. This research report has not been submitted before for any degree or examination in any other university. Ethics clearance was obtained for this study and the reference number is: H120509.



Ewa M. Wojtasik

5th day of September 2013

ABSTRACT

In South Africa, indigenous plant species are used and traded for traditional medicine (*muthi*) and so are alien plant species. A literature review of 40 previous studies and survey work at various outlets, including *muthi* markets and *muthi* shops in Johannesburg, Durban and Pretoria, found that 320 alien plant species are used and/or sold for traditional medicine in South Africa. Fifty three of the 320 species were found to have weed and/or invader status. Surveys at Faraday and Warwick *muthi* markets in Johannesburg and Durban respectively as well as *muthi* shops in Johannesburg, Durban and Pretoria were conducted from October 2010 to February 2011. The following aspects regarding the plant material traded were recorded: the differences in the number of volumes traded; the differences in the number of alien species sold in the markets and shops (and also in Indian and Black-owned shops); the source and origins of these and the viability of propagules sold in the *muthi* trade. The surveys found that 49 alien plant species were sold and approximately 87 x 50kg-size bags of alien plant material was present in the markets and shops during the time of the survey. *Muthi* shops sold more than double the number of alien plant species than were sold in the markets and the same result was found for Indian versus Black-owned shops. Alien species were either harvested in South Africa, predominantly in KwaZulu-Natal (KZN), or imported from India. Indian-owned *muthi* shops sold more species imported from India than alien species that were naturalised and harvested in South Africa. In contrast, the majority of alien species sold at markets and Black-owned shops were harvested in KZN. Viability tests found that 24% of alien plant species sold in this study had greater than 50% viability. Six invasive species are traded in low volumes with viable propagules sold for five of these, highlighting a possibility of spreading through the traditional medicine trade. The study concluded that the total trade in alien plant species is trivial in comparison to the trade of indigenous plant species.

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CHAPTER 1 – GENERAL INTRODUCTION

Traditional medicine (TM), otherwise generally known in the study as *muthi* (meaning medicine in isiZulu), plays a significant role in the lives of many modern Black South Africans (Botha *et al.*, 2001). Approximately 27 million people use traditional medicine in South Africa (Mander *et al.*, 2007). The TM trade consists of 'informal' *muthi* markets and 'formal' sector *muthi* shops (MS) (Williams *et al.*, 1997; Williams, 2003). More than 2000 indigenous plant species are used for TM in South Africa (Williams *et al.*, 2013), with some studies recording both indigenous and alien plant species (Hutchings, 1989; Dold and Cocks, 2000; Arnold *et al.*, 2002; Williams *et al.*, 2007a). Alien plant species are often referred to as exotic, non-native, non-indigenous or introduced plants that are in an area outside of their native range. An introduced plant here refers to a plant part or a propagule that has been transported by humans across a major geographic barrier (Richardson *et al.*, 2000).

The indigenous plant species sold in the *muthi* trade are mostly wild harvested within various provinces in South Africa, with the bulk harvested in KwaZulu-Natal (KZN) (Williams, 1992; Williams, 1997; Botha *et al.*, 2004a). Similarly, many of the alien plant species sold are harvested close to TM markets (Dold and Cocks, 2000; Bhat and Moskovitz, 2009). Furthermore, imported alien plant species are sold for TM (Williams *et al.*, 2000; Mander *et al.*, 2007; Stafford *et al.*, 2008). These alien species are mainly imported from India by Indian traders (mainly Tamil-speaking Hindus), a consequence of historical factors resulting from Indian indentured labourers having been brought to South Africa in the 1860s and the trade links that currently exist between the province of Tamil Nadu and South Africa (Flint, 2006; Williams, 2007). No study has investigated the potential links between the establishment and persistence of alien plant species in South Africa and the Indian plant species that were used for TM and food by the descendants of the Indian indentured labourers. This study fills that niche and investigates alien plant species other than those from India that are used and sold for traditional medicine in South Africa.

1.1 Traditional medicine trade

1.1.1 **What is traditional medicine?**

Traditional medicine, according to the World Health Organization, is defined as health practices, knowledge, beliefs and approaches that incorporate plant, animal and mineral-based medicines, spiritual therapies, manual techniques and exercises, applied singly or in combination to treat, diagnose and prevent illnesses or maintain wellbeing (Pieroni *et al.*, 2008). The difference between traditional medicine and western medicine is that traditional medicine is also culturally supportive, personal and holistic in its approach, whereas western medicine is usually organ-orientated and specific in its approach (Fako, 1978). Traditional medicine is used by most cultures, but has been best studied in Africa, China and India, where it coexists alongside Western allopathic medicine (which includes the prescription of pills, syrups and antibiotics by medical doctors) and Western herbalism (Nel *et al.*, 2004).

Traditional medicine practices are dynamic and adaptive, and the natural resources used by communities are harvested from nearby regions, provinces and surrounding countries (Mander, 1998a; Dold and Cocks, 2000; Van Wyk and Gericke, 2003; Botha *et al.*, 2004a). The more effort required by the harvester to gather medicinal products, the more expensive the product becomes (Dold and Cocks, 2005; Williams, 2007). 'Effort' refers to the distance the harvester has to travel, and possible expenses such as taxi or bus fares involved in obtaining the resources. Prices of traditional medicines are also influenced by the availability or scarcity of resources over time (seasonal) and consumer demand (Williams, 2007).

Medicinal plants are used for TM, as well as for spiritual or cultural rituals and cosmetic purposes (Dold and Cocks, 2002; Dold and Cocks, 2005). Plants are usually burned, crushed or boiled before they are used (Van Wyk *et al.*, 1997), therefore undergoing some kind of preparation process.

1.1.2 **Factors influencing the traditional medicine trade**

Traditional medicine is used by a large proportion of Black South Africans due to its affordability and its cultural value (Cunningham, 1988; Botha *et al.*, 2001). Cultural value refers to African people from all levels of modern South Africa who still make use of *muthi* as their first response to illness or social problems irrespective of their age, education or income level (Williams *et al.*, 1997; Dold and Cocks, 2002; Mander *et al.*, 2007).

The medicinal trade is stimulated by the following factors: high population growth, rapid urbanization, unemployment and the high cultural value of traditional medicines (Dold and Cocks, 2002). These factors cause a continuous increase in the demand for TM (Mander, 1998a; Dold and Cocks, 2002). Plant products that are used and sold include bark, roots, bulbs, leaves, fruit, tubers, seeds, stems and whole plants (Van Wyk *et al.*, 1997; Van Wyk and Gericke, 2003; Mander *et al.*, 2007).

1.1.3 **The two sectors of the traditional medicine trade**

The TM trade broadly consists of 'informal' and 'formal sectors'. The informal sector refers to transient commercial gatherers, traditional healers and hawkers who sell products from pavements or open *muthi* markets (Williams, 2003). The formal sector is represented by herb-traders and traditional healers that sell various products from premises known as *muthi* shops (Williams *et al.*, 1997). Some shops also sell packaged medicines that have been processed either into tablet, powder or liquid form and are supplied by manufacturers (Mander *et al.*, 2007; E.M.Wojtasik, pers. obs.).

1.1.4 **Faraday and Warwick traditional medicine market**

Faraday and Warwick traditional medicine markets are the two largest markets in South Africa and accommodate both harvesters and traders. Harvesters gather medicinal products themselves, whereas traders tend to purchase products from harvesters and from traders in other markets (Mander, 1998a; Williams *et al.*, 2007a). Traders may also be harvesters of medicinal plants. Faraday and Warwick markets are situated close to transport nodes (*viz*. taxi ranks) and currently accommodate approximately 200 and 300 traders respectively. Faraday market is located adjacent to the M2 highway in Johannesburg and the Warwick market is located in the periphery of Durban's central business district (Figure 1.1).

a) b)



Figure 1.1 Google Earth images (2007) of the traditional medicine markets and the trading blocks that were surveyed at a) Faraday market in Johannesburg, and b) Warwick Market in Durban.

Faraday is the only informal *muthi* market in the Witwatersrand and is also the wholesale and retail centre for trade in indigenous medicines in the Witwatersrand (Williams, 2003). Most of the plants sold at Faraday have been bought from suppliers from KZN (harvesters or the Warwick market) (Williams, 1992; E.M.Wojtasik, pers. obs.).

Products sold at the markets are usually sold according to 'handful' volumes and not according to a specific mass (Williams *et al.*, 2007a). The 'handful' volumes are sold at a set unit price which is influenced by inflation and increasing harvesting costs. In 1995, the set unit price in Faraday was R2, and increased to R5 in 2001 (Williams *et al.*, 2007a). Thereafter, from the year 2001 to 2011, the set unit price increased to R10.

1.1.5 ***Muthi* shops**

Muthi shops (MS) are often located close to the city or central business districts (Williams *et al.*, 1997; E.M.Wojtasik, pers. obs.). *Muthi* shops usually have consulting rooms and display their stock in jars or bottles and also sometimes sell raw (unchopped or unprocessed) plant material (Bye and Dutton, 1991; E.M.Wojtasik, pers. obs.). In 1994 there were 244 MS on the Witwatersrand, of which 52% were owned by African traders, 25% were owned by Indian traders, 16% owned by White traders, 1% by Coloured owners and 6% were not determined (Williams *et al.*, 1997). Although the exact number of MS that are still active is unknown, it

has most likely decreased since 1994; this decline can probably be attributed to the increasing number of harvesters and hawkers, i.e. traders selling products in *muthi* markets selling the same species at cheaper prices (Williams *et al.*, 2005a; Williams *et al.*, 2007a).

In addition to the MS scattered throughout the Johannesburg Central Business District (CBD), many are located in the Mai Mai Bazaar - a place where traditional healers practise and trade in traditional medicine. Located in the south-eastern section of the Johannesburg CBD, Mai Mai was established c.1890 and used to make up 32% of the herb-traders in Johannesburg (Williams, 1997). In 2003 Mai Mai consisted of 176 shops that were owned by mostly herb-traders (Thale, 2003). In 2012 Mai Mai had 18 shops selling traditional medicine, with most shops having a consultation room. Except for a few herb-traders, these shops are mainly occupied by traditional healers (E.M.Wojtasik, pers. obs.). The remainder of the shops in Mai Mai are occupied by traders producing shields, traditional clothing and a range of other African products. Several of the shops belong to a business that makes coffins and cupboards (E.M.Wojtasik, pers. obs.). The Pretoria CBD also has MS, although an unknown number; four were found with the help of Dr Stefan Nesser who at the time worked at the Weeds Research Division, ARC - Plant Protection Research Institute.

1.2 Historical interactions between African and Indian people and the establishment of the traditional medicine trade

Indians in the South African import a variety of plants from India used as traditional medicine (Williams, 1992; Williams, 2007). The involvement of Indians in the trade dates to c.1860 when Indian indentured labourers were recruited by the British governor in KZN, which was a British colony at the time, to work in the sugarcane plantations as a result of a shortage of Zulu labour (Cohen, 1995; Flint, 2006; Williams, 2007). They brought their medicinal culture with them by bringing the seeds of their medicinal plants with them from India, which they planted when they arrived (Cooppan, 2010). The indentured Indians that came to South Africa were mainly the working class Tamil-speaking Hindus, and they had a large amount of interaction with the Zulu people through working together in the sugar fields (Williams, 2007). In an interview with Loganathan Govender in 1997, Nesvåg (1999) reported that the early Indian immigrants learned about the medicines of the local Black population, who in turn learned about the medicinal practices (probably Ayurvedic) from the immigrant Indian population (Nesvåg, 1999). African and Indian interactions increased as

indentured labourers spread to other industries, such as the coal mining, railroad construction and farming, and free-Indians moved into rural areas taking up agriculture. Many Indians moved to African communities to escape the degradation of the indenture, with some Indians deciding to live under African chiefs instead of returning to India (Flint, 2006).

According to Nesvåg (1999) initially segregation and apartheid laws made it almost impossible for Indians and Africans to start formal businesses in Durban. The Durban *muthi* trade was thus forced underground or out to the new townships. Illegal underground mail-orders were the means by which the big *muthi* companies operated. Legislation in parliament as early as 1928 restricted the *muthi* trade as the licensing of 'native medicine men and herbalists', and was only allowed in KZN (Dauskardt, 1990). The opening of Indian *muthi* shops in Durban started in the 1940s in the Indian commercial district between Central Park and Warwick Avenue. The Durban trade was dominated by Indian traders until the late 1980s and the early1990s (Nesvåg, 1999).

The *muthi* trade was, however, not restricted to KZN, as it spread to the Witwatersrand when early African urbanisation occurred due to the need for cheap labour on the gold mines (Dauskardt, 1990). The mines and mine hostels were where the herbalists and *muthi* traders established their practises (Williams *et al.*, 1997).

Many ex-indentured Indians moved to Johannesburg during the developmental stages of the Witwatersrand, which enabled them to fill a niche for the emerging demand of traditional medicine since they were themselves users (Dauskardt, 1991). This niche was filled by establishing herbal pharmacies or '*muthi*' shops with White traders as owners, since Indians weren't able to operate with African traders in 'white areas' or the CBD (Williams, 2007). In spite of this, the Indian traders learned isiZulu, lived and worked with the African population and therefore also used the Zulu medicinal knowledge which they continually developed by employing Zulu traditional healers to work in their shops (Flint, 2006; Williams, 2007). Indian traders not only practiced TM based on Zulu traditional knowledge, but also used existing Indian knowledge to make various medicines (Flint, 2006). Many plants were imported from India for Ayurvedic medicines. However, on certain occasions when the Indian traders ran short of stock they utilised the Indian flora that grew as alien plants in South Africa (Flint, 2006).

The interaction between Indian and African people was also influenced by other factors. In the early 1900s there were numerous devastating events such as droughts, locust infestations, famines, epidemic events, as well as social crises and increased taxation in South Africa. This lead to many African healers travelling the countryside and later on, towards the twentieth century, the Indian healers did the same (Flint, 2006).

In Flint's (2006) review on African-Indian encounters and therapeutics in SA, she reports that government officials in the 1930s and 1940s would regularly stop African and Indian traders and demand paperwork to ensure compliance with labour laws. Therefore both Africans and Indians sought to avoid prosecution by obtaining an *inyanga's* (a 'native' doctor) licence, but due to their race Indians were not granted one. Finally Indian *inyangas* got around the legal restriction and obtained at first hawking and then general dealers' licences. Between 1915 and the late 1920s the *muthi* trade officially included the Indians as well as African *inyangas* and street traders (Flint, 2006). Indians predominantly traded from shops, which differed from street traders in that it enabled the traders to stock a larger diversity of products as well as larger quantities, allowed stocks to be better preserved, and traders were also able to have private consultation rooms which provided privacy and respect to the customers (Flint, 2006). Indian shop traders had a commercial advantage over the African traders because, even though the government restricted Africans and Indians purchasing property, Indians could generally obtain shops closer to town centres and more importantly near main transportation hubs. Many African informal traders sold products on the street. This type of trade was prohibited in the 1930s and 1940s, therefore forcing African traders to open up *muthi* shops (Flint, 2006).

During the Apartheid era, African *muthi* traders were prevented from trading in the Johannesburg CBD (Dauskardt, 1992). However, the Mai Mai Bazaar was an exception. Here the African *muthi* trader could occupy a stall and sell products while the 'doctor' in the corner concocted brews (Dauskardt, 1992). According to Williams *et al*. (1997), the *muthi* trade of the Witwatersrand was essentially made up of African traders in the townships and White-owned and Indian businesses in the CBD until the Apartheid laws were terminated after the May 1994 elections. Since then there has been a decline in the number of White-owned and

Indian businesses in the CBD and an increase in the number of commercial gatherers and hawkers (Williams *et al*. 1997).

By the mid 1980s, there were a large number of Indian-owned traditional medicine shops in Durban's Grey Street area; however, after the end of Apartheid in 1994, African street trading increased. This had a negative effect on Indian *muthi* shops and their number drastically decreased (Flint, 2006; Williams, 2007). Many African traders had incorporated Indian herbs and coloured powders into their medicines, even the displays in African-owned shops were like those of Indian shops showing how Indian and African interactions had advanced (Flint, 2006). Some of the Indian herbs and spices used within African pharmacopoeia include ginger, asafoetida (*Ferula assa-foetida*), turmeric (*Curcuma longa*), cinnamon (*Cinnamomum verum*), cumin (*Cuminum cyminum*), fennel seeds (*Foeniculum vulgare*), clove (*Syzygium aromaticum*), nutmeg (*Myristica fragrans*), bitter oils from the syringa plant (*Melia azedarach*), senna leaf (*Cassia angustifolia*), holy basil (*Ocimum tenuiflorum*), croton seeds (*Croton sp*.), betel nuts (*Areca catechu*), frankincense (*Boswellia sacra*) and myrrh (*Commiphora myrrha*). Africans borrowed the method in which the Indians prepared aloes, i.e. burning and crushing it into a fine powder (Flint, 2006). Many African healers preferred using Indian substances or medicines since they could read the instructions on the patent medicine box. All of the above indicate historical interactions between Indians, Africans and Whites around the *muthi* trade and also indicate how in particular Indians contributed to traditional medicine practices in South Africa (Flint, 2006).

1.3 Alien plant species

1.3.1 **Alien plants and transportation from their native regions**

Alien plant species are plants that occur outside of their native regions (Catford *et al.*, 2009) and belong to all taxonomic groups (ISSG, 2000). Globalisation, trade and tourism have been the main causes of alien plant transportation around the world (ISSG, 2000; Catford *et al.*, 2009). Introductions of alien species have either been intentional or unintentional, (ISSG, 2000; Lowe *et al.*, 2000; Pimentel *et al.*, 2000), and many unintentional or accidental introductions have occurred as a result of alien species being transported with other goods (e.g. animal fodder). Alien species also travel through diverse corridors such as roads, railways and canals (ISSG, 2008; Hulme, 2009).

1.3.2 **Definitions of alien plant terms**

The terms “naturalized plants”, “weeds” and “pests” have been defined differently by various authors (Richardson *et al.*, 2000; Henderson, 2001a; Pyšek *et al.*, 2004a; Klein, 2006; Pyšek and Richardson, 2006; Catford *et al.*, 2009). For the purpose of this study, the terms will be used as defined by Henderson (2001a), Pyšek *et al*. (2004a), Klein (2007) and Catford *et al*. (2009). Three categories are currently used to classify alien invader species and these are explained below. The categories are adapted from The Conservation of Agricultural Resources Act, 1983: Act No 43 of 1983 [CARA] and are given in Table 1.1 (Henderson, 2001a).

1.3.3 **Conflicts of interest: are alien plant species beneficial or costly?**

The benefits of introduced alien species

Intentional introductions of alien plant species have taken place over numerous years for a variety of reasons, ranging from the introduction of livestock, pets, medical herbs, sport uses and agents used for biological pest control (Kornaś, 1990; Pimentel *et al.*, 2000; Le Maitre *et al.*, 2004). In South Africa, thousands of plant species have been introduced for the production of crops, for firewood (e.g. many *Acacia* species) timber, for stabilizing sand dunes, fodder (*Prosopis* species), as garden ornamentals and as barrier and hedge plants (Kornaś, 1990; Pimentel *et al.*, 2000; Van Wilgen *et al.*, 2001).

Other benefits of introduced alien plants include ones that support commercial activities such as: forestry plantations (*Pinus* species); production of food (*Opuntia* species); building materials (*Arundo donax*, *Acacia saligna*); fodder (*Prosopis* species); agroforestry components, or the production of nectar for bees (*Eucalyptus* species); and, aesthetic or utilitarian value (ornamentals, shade trees or windbreaks) (Richardson and Van Wilgen, 2004). Forestry plantations play an important role in the South African economy; in the late 1990s the value was estimated at US$ 300 million annually, or 2% of the GDP and employing over 100 000 people (Moran *et al.*, 2000; Van Wilgen *et al.*, 2001).

Some of the benefits of alien plants create conflicts of interest because many of these species, especially *Acacia* spp. (used for firewood, charcoal and building materials), *Pinus* spp. (used in forestry plantations) and *Eucalyptus* spp. (used to produce timber, poles, firewood, nectar and pollen for the production of honey), also cause significant environmental impacts (Moran *et al.*, 2000; Van Wilgen *et al.*, 2001; De Wit *et al.*, 2002; Forsyth *et al.*, 2004; Richardson and Van Wilgen, 2004).

Costs of alien species

The environmental impacts caused by the invaders *Acacia, Pinus* and *Eucalyptus* include reduction of stream flow, and reducing yields from dams by taking up large amounts of water (Forsyth *et al.*, 2004; Richardson and Van Wilgen, 2004). *Pinus* and *Acacia* cover a large proportion of South Africa, and *Acacia mearnsii* in particular has spread over roughly 2.5 million ha in South Africa and causes significant negative impacts on water resources, biodiversity, and the stability and integrity of riparian ecosystems (Van Wilgen *et al.*, 2001; De Wit *et al.*, 2002).

Encroachment by alien plants has been described as the third most severe threat to native plant taxa following habitat loss and habitat degradation. To date, seven taxa in South Africa have either gone Extinct, are Extinct in the Wild or are Critically Endangered and Presumed Extinct due to alien invasive plants (Raimondo and von Staden, 2009). . Furthermore, the Red List Assessment of South African plants found that 5.6% of 20,456 assessed South African plant taxa are threatened by alien invasive plants (Raimondo and von Staden, 2009). Some of the negative impacts caused by alien invasive plants include: transforming ecosystems by using excessive amounts of resources (such as light and oxygen), adding resources (particularly nitrogen), promoting or suppressing fires, promoting erosion, accumulating litter or redistributing salt. These impacts lead to alterations in the landscape and ultimately changes the flow, availability and quality of nutrient resources in biogeochemical cycles, modified trophic resources within food webs and changes in physical resources such as habitat or space, light, sediment and water (Pimentel *et al.*, 2000; Le Maitre *et al.*, 2002; Grace *et al.*, 2004; Pyšek and Richardson, 2006; Raimondo and von Staden, 2009).

Table 1.1. Definitions of alien plant terms and categories of alien invasive plants (Henderson, 2001a; Pyšek *et al.*, 2004a; Klein, 2007; Catford *et al.*, 2009). Categories of alien invasive plants are defined in terms of CARA (Conservation of Agricultural Resources Act).

Definition of Alien invasive plants	
Naturalized plants	Alien plants that sustain self-replacing populations without direct human intervention (or in spite of human intervention) by recruitment from seed or ramet (tillers, tubers, bulbs, fragments, etc.) capable of independent growth.
Invasive alien plants	Invasive plants are a subset of naturalized plants that produce reproductive offspring. Offspring are usually produced in very large numbers and at considerable distances from the parent plants, and therefore have the potential to spread over a large area.
Weeds	Weeds are alien plants that grow in unwanted areas or in permanently human-disturbed habitats and are independent of human intervention to reproduce or survive. 'Weed' is a subjective term that depends on the intention or opinion of the person who uses it. This is owing to the fact that although an alien plant may be in an area where it is unwanted, it can also be found in an area where it may be useful. For example, a guava tree may be considered as a valuable crop to a farmer, or unwanted in a game reserve. The following distinctions can be made: • Agrestal weeds are weeds found on cultivated land. • Ruderal weeds are weeds found on waste lands. • Environmental weeds are invaders of natural and semi-natural habitats.
Pests	Invasive species that harm other species or human interest.
Categories of Alien invasive plants	
Category 1 plants – Declared weeds	• Prohibited from being on any land or water surface in South Africa. • Must be controlled or eradicated where possible, unless occurring in biological control reserves.
Category 2 plants – Plant invaders	• Only allowed in demarcated areas under controlled conditions. • Must be controlled outside of demarcated areas or eradicated where possible, unless occurring in biological control reserves. • Prohibited within 30m of the 1:50 year floodline of watercourses or wetlands, unless authorization has been granted. • Import and trade of propagative material are only allowed to permit holders.
Category 3 plants – Plant invaders	• No further plantings are allowed (except under special permission). • No trade of propagative material. • Existing plants must remain but must be prevented from spreading. • Prohibited within 30m of the 1:50 year floodline of watercourses or wetlands, or as directed by the executive officer.

All of these impacts have tremendous costs to the global economy. A recent overview for seven different countries estimated the global cost of control programmes and the total costs of damage caused by invader species to amount to US$314 billion per year (Le Maitre *et al.*, 2004; Cook *et al.*, 2007). South Africa has approximately 10.1 million ha (6.8% of the country) that has been invaded by alien invasive plant species (Le Maitre *et al.*, 2002; Nel *et al.*, 2004). This costs South Africans tens of billions of rand annually in lost agricultural productivity and resources spent on weed control (Le Maitre *et al.*, 2004). Bearing this in mind, it is clear that the benefits and costs or impacts of alien plant species are a controversial issue, and are sometimes based on human perceptions (Richardson *et al.*, 2000; Pyšek and Richardson, 2006). Van Wilgen *et al*. (Westman, 1990; Lodge, 1993; ISSG, 2000) explain that there is no standard system for objectively quantifying environmental impacts, due to various authors measuring impacts in different ways. Nonetheless, this point was raised to once again indicate the controversy in the 'pros' and 'cons' of alien plants and also to state that the aim of this study is not to indicate whether the trade of alien plants is beneficial or detrimental, but merely to investigate the involvement the *muthi* trade has in the movement of alien species in South Africa.

1.3.4 **Traits of alien plant species**

Alien plants are sometimes a threat to native taxa, especially in the absence of natural enemies and the lack of fires. Other generalized characteristics that may indicate invasive possibilities include traits such as: high population growth rate, small seed size, abundant seed production, high genotypic and phenotypic plasticity, short generation times, long-range dispersal ability, single parent reproduction, high genetic variability, high and early fecundity and fertility and generalized pollination systems (wind, generalized insect or self-pollination) (Westman, 1990; Lodge, 1993; ISSG, 2000; Pimentel *et al.*, 2000; Grace *et al.*, 2004; ISSG, 2008; Catford *et al.*, 2009). These traits may, however, differ between species (Richardson and Pyšek, 2006).

1.3.5 **"Tens rule" and the stages involved in alien plants becoming invasive**

Alien plant and animal species have been transported and traded for millennia (Hulme, 2009), resulting in thousands of species being introduced into new regions around the world. Not all

of the introduced species have become invasive, but the "tens rule" attempts to quantify the probabilities of introduced species becoming pests (Williamson *et al.*, 1986; Hulme, 2003). The "tens rule" states that roughly 10% of introduced species will become naturalised, with 10% of these becoming pests or invasive (Williamson et al., 1986; Lockwood et al., 2001; Hulme, 2003). The "tens rule" was approximated by Williamson *et al*. (1986) in Britain and was a rough estimate that should simply be interpreted as a guideline when determining how many established alien plants will become pests (Williamson *et al*., 1986; Lodge, 1993; Richardson and Pyšek, 2006). The "tens rule" is used as a benchmark for comparing the results of this project. The phases that alien plants undergo to reach 'successful invasion' have been defined by various authors (Richardson *et al.*, 2000; Weber, 2003; Radosevich *et al.*, 2007; Catford *et al.*, 2009), and for the purpose of this study the stages defined by Catford *et al*. (2009) will be used to categorise at which stage or process the traded alien plant species are found (Table 1.2). Products sold in the *muthi* trade will most probably be found between stages 1-5.

Table 1.2. The stages and processes involved in alien plants becoming successful invaders and harmful pests. Stage 6 is equivalent to CARA (Conservation of Agricultural Resources Act) Categories 1, 2 and 3 (Catford *et al.*, 2009).

Stage/ Process	1/ Transport	2/ Introduction	3/ Colonization	4/ Naturalization	5/ Spread	6/ Impact
Definition	Movement of plants or plant propagules to new region.	Arrival of plant or plant propagules into new region.	Survival of introduced plants.	Survival and reproduction, enabling pioneer population to be self-sustaining.	Dispersal of propagules and spread of populations outside of area where first introduced.	Harmful impact of species to ecology and economy.
Common terms used				Introduced Weed	Naturalized Invasive	Noxious/ Pest

1.3.6 **Alien plant species that are traded for traditional medicine in South Africa**

Alien plant species have been used for traditional medicine since the 18th century in South Africa (Dold and Cocks, 2000), and many studies show that they are still being used today (Cunningham, 1988; Tait and Cunningham, 1988; Williams, 1992; Dold and Cocks, 2000; Williams *et al.*, 2000; Botha *et al.*, 2001; Williams *et al.*, 2001; Dold and Cocks, 2002; Grace *et al.*, 2003; Grace *et al.*, 2004; Nel *et al.*, 2004; Ndawonde *et al.*, 2007; Williams *et al.*,

2007a). A number of alien plant are imported from India and are sold to Indian shop owners on the Witwatersrand and in Durban (Williams, 1992). Thereafter, the plants are purchased by Indian and African customers (S. Dorasammy pers. comm. 2009).

1.4 Aims and Objectives

1.4.1 **Aim**

The aim of this study is to investigate the richness and diversity of alien ethnomedicinal plant taxa used and sold for traditional medicine in South Africa by conducting surveys at the Faraday and Warwick TM markets and *muthi* shops in Johannesburg, Durban and Pretoria.

1.4.2 **Objectives**

Objective 1:

To create an inventory that records which alien plant species are used and sold for traditional medicine in markets and *muthi* shops (MS) in Johannesburg, Durban and Pretoria. The inventory consists of the following information: botanical name, author, family name, status (as a weed, Category 1, 2 or 3, etc), vernacular name (s) and language (s), common name, plant part used, origin and frequency of occurrence (amount of times a species was recorded in this study). Vouchered herbarium specimens of the alien plant species sold in the markets and MS in Johannesburg, Durban and Pretoria will be deposited in a reference collection at the C.E. Moss Herbarium, University of the Witwatersrand.

To create a second inventory documenting which alien plant species have been recorded in the past as having been used and sold for traditional medicine in South Africa, by conducting a literature review. The literature review includes collecting the following information concerning the alien medicinal plant species: botanical name, author, family name, common name, origin, status (as a weed, Category 1, 2 or 3, etc), whether the species was used/or sold for medicne, and the literature source for the study citing the alien plants.

Objective 2:

To conduct experiments to determine how viable the alien plant species sold are, by germinating or otherwise growing viable propagules purchased during surveys with traders of traditional medicine. The objective is also to determine whether the viability of alien species sold in different outlets (*muthi* markets or shops) is the same.

Objective 3:

To quantify the volume of alien plant species sold in the *muthi* markets and shops in Johannesburg, Durban and Pretoria, and to verify whether the volume of alien species sold in the different outlets is the same.

Objective 4:

To determine the source of the alien plant species sold in the *muthi* markets and shops in Johannesburg, Durban and Pretoria with special reference to Indian imports and introductions. To determine whether the source of alien species sold in different outlets is similar.

Objective 5:

To determine the biogeographical origin of the alien plant species sold in the *muthi* markets and shops in Johannesburg, Durban and Pretoria and verify whether the origins of alien species sold in different outlets are the same.

Objective 6:

To analyse the species richness and diversity of alien plant species sold in Johannesburg, Durban and Pretoria, and to determine whether the diversity of alien species sold in different outlets is the same.

Objective 7:

To determine the total number of plants species and families sold in the medicinal plant trade including both alien and indigenous plant species, recorded during this study, as well as during earlier studies in South Africa

CHAPTER 2 – GENERAL METHODS

This study investigated alien plant species sold in different retail outlets (*muthi* shops and markets), by different trader race groups located in different cities, and determined where the alien plant species sold in the retail outlets originated from. Figure 2.1 outlines the structure of this study.

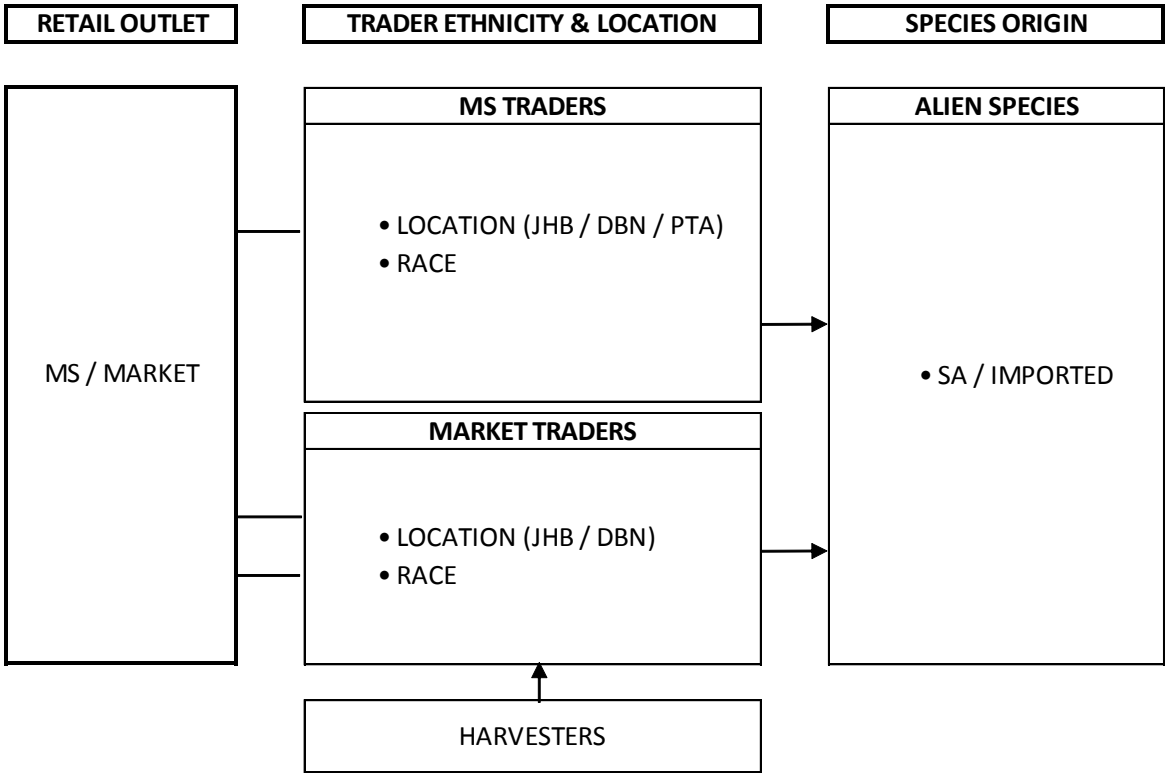


Figure 2.1. Sectors of the traditional medicine trade in alien plant species that were investigated. These sectors include both *muthi* shops (MS) and *muthi* market outlets analysed by their geographical location and trader race group attributes. These relationships to the origin of the alien plant species sold were also investigated. JHB=Johannesburg; DBN=Durban; PTA=Pretoria.

2.1 Traditional medicine market and *muthi* shop surveys in Johannesburg, Durban and Pretoria

2.1.1 **Pre-survey visits**

Preliminary visits to the Faraday and Warwick markets were conducted on the 12th, 13th and 19th of October 2010, and the 1st and 2nd of November 2010 respectively. The Faraday preliminary visit involved detecting alien plant species sold, and was carried out with the assistance of Dr V.L. Williams and Mr D. McCallum, botanists from the University of the

Witwatersrand. In preparation for the Warwick preliminary visits, a meeting with a Zulu translator was held to discuss the questionnaire used (Appendix 3) and proposed structure of the survey. Another meeting prior to the Warwick preliminary visit was held with Dr N.R. Crouch (a botanist from the South African National Biodiversity Institute in Durban), in order to categorize certain plant species that were purchased from Faraday's preliminary visit, as either alien or indigenous. The Warwick preliminary visit comprised of walking through the market accompanied by a Zulu translator and Dr Crouch, and any alien plant species sold at the market were identified, recorded, photographed and purchased for the set unit price of R10. Permission by the chairperson of each market was granted by signing informed consent forms (Appendix 1).

The alien plant species observed at both Faraday and Warwick markets were combined into an amalgamated checklist and used during the main surveys. In addition to these species, alien plants recorded in *Medicinal Plants Traded on South Africa's Eastern Seaboard* (Von Ahlefeldt *et al.*, 2003) were added to the list (Appendix 2). Furthermore, photographs of alien species in Von Ahlefeldt *et al.* (2003) were used to identify several plants recorded in the markets.

A pilot study was conducted with a *muthi* shop owner from Centurion, Mr S. Dorasamy, who assisted with a previous study (Wojtasik, 2009). He was asked to help refine the questionnaire and to provide contact details of other shop owners that could be interviewed.

2.1.2 **Market and *muthi* shop surveys**

Faraday market survey

The main Faraday market survey was conducted on the 27th, 28th October and 8th, 9th, 13th, 14th December 2010. Semi-structured interviews were conducted with every trader who was seen to be selling alien species (n=32 traders). The total number of traders in the market was also counted in order to determine the percentage of traders selling alien plant species.

Warwick market survey

The Warwick market survey was conducted on the 3-4th of November 2010. Semi-structured interviews with 28 traders selling alien plant species were conducted, and the total number of traders in the market were counted.

Interviewing each trader in Warwick took longer than anticipated, with delays in translation from English to Zulu, plants being stacked underneath other plants, interruptions by customers and time constraints in a two day survey. This implied that if the whole market was to be surveyed, then a stratified random sampling strategy should be used. Therefore every fourth trader on either side of the main walkway running through the market was interviewed. If the fourth trader did not stock any alien plants, the closest adjacent trader that sold an alien plant was interviewed. Some traders stocked more than four of the species that were on the original list of alien plants used for this study (Appendix 2). These traders were asked about the species that were not yet recorded during earlier interviews, or where fewer observations were recorded.

Muthi* shop *surveys

Seventeen *muthi* shops were surveyed in total: three in Durban, four in Pretoria and 10 in various parts of Johannesburg. The shops Durban survyed during the 3rd - 5th of November 2010 were Indian-owned, and one outlet was a Indian wholesaler called A.M. Khan Wholesaler. *Muthi* shop owners were asked specifically "*Do you sell any plants that are used for TM that come from India*?" as well as the other questions in the questionnaire. In addition, the following question was also asked: "*Who do you purchase your stock from?*"

The four Pretoria shops surveyed on the 19th and 20th January 2011 were all owned by Indian traders. The first shop had mostly processed material (i.e. cut into pieces and some even liquidised) and packaged products and a few raw medicinal plants. The last three shops differed in that all of their stock was still in raw form. The Johannesburg shops were surveyed on the 11th, 18th and 20th of January and on the 9th and 16th of February 2011; most were based at Mai Mai and all 10 were Black.

Data collection

Data collected during the surveys were recorded in questionnaires. Questionnaires consisting of two parts were used during the surveys: 1) trader information, and 2) information relating to each alien plant that was traded (Appendix 3) Questionnaires differed slightly for the *muthi*

market and shop surveys. Questions regarding the uses of alien plant species were avoided to prevent compromising the intellectual property rights of the traders (Williams *et al*., 2000).

The data collected during the surveys was partly qualitative and partly quantitative. Qualitative information varied from recording the vernacular name of an alien plant specimen in question, the botanical name of the plant (if known), the plant part type (e.g. bark, leaves or bulb), whether the plant was harvested or bought, the source area of plant (i.e. where harvested or purchased from), and the typical preparation method of the plant in order to be used (e.g. crushed, boiled). Understanding whether the plant was scattered or boiled gives some insight as to the possibility of seeds being scattered for a ritual and in this way being moved and landing on the ground and possibly germinating if conditions are favourable. Plants traded in the *muthi* markets are named according to their ethnospecies name, or vernacular name which is an ethnic or common name given to a plant or a group of plants (Hanazaki *et al.*, 2000; Williams, 2003; Williams *et al.*, 2005a; Williams *et al.*, 2007a). A common occurrence within the *muthi* trade is that different plant species have the same vernacular name. Martin (1995) calls this process "under-differentiation", where a single local name is used as a generic term for several different plant species.

The quantitative data that was collected included: estimating the quantity of the plant present at the trader's stall, when and how much (e.g. bag size) of the plant was purchased or harvested, and how frequently the plant was obtained. In addition to the questions stated on the questionnaire, the following points were also enquired about: meanings of vernacular names; if any other plants were used as substitutes if a particular plant was out of stock; does the plant grow easily; will customers grow it themselves? The meanings of vernacular names were recorded if the trader was willing to give that information. These meanings were of interest because the name could relate to the use of the specific plant or could give additional information on the plant. During the interviewing process, notes were taken if the trader pronounced or gave a different name for a specific alien plant species. Lastly plant specimens were purchased, identified and deposited as voucher specimens in a reference collection at the C.E. Moss Herbarium, University of the Witwatersrand.

2.1.3 **Non-survey research**

The inventory constructed from the *muthi* market & shop surveys was compared to that of previous studies. The former inventory consisted of all the alien plant species recorded as sold in this study. The latter, referred to as the literature review, includes alien plant species that were cited as used for traditional medicine in South Africa as recorded in previous studies which are listed below Appendix 5. These studies either mentioned that the alien plant species were used only for traditional medicine or used and sold. These two inventories are referred to and compared in this report. Further comparisons were made between the first inventory, i.e. the alien plant species recorded in this study, and work done by Williams *et al.* (2013) where the total number of indigenous plant species used for traditional medicine in South Africa were recorded.

2.1.4 **Data analyses**

Throughout the report, the results from the individual Faraday and Warwick *muthi* markets, both markets combined, the individual *muthi* shops (MS) (in Johannesburg, Durban and Pretoria), and all MS combined were analysed under the section 'Type of retail outlet'. *Muthi* shop data was again analysed according to race of MS owner, by comparing Black versus Indian-owned shops under the section 'Race of retail outlet owner'. Market and shop surveys were also analysed between the alien species recorded in the different cities of Johannesburg and in Durban in the section 'Region of retail outlet'. Data from the Faraday market and Johannesburg MS were also combined, and was referred to as 'Johannesburg overall'. 'Durban overall' included the Warwick market and Durban MS and was compared with Johannesburg overall. Pretoria MS data was not included in the Johannesburg or Durban overall. Data from this whole study was referred to as 'all outlets'.

CHAPTER 3: INVENTORY OF ALIEN PLANT SPECIES SOLD IN THE SOUTH AFRICAN TRADITIONAL MEDICINE TRADE

3.1 Introduction

The traditional medicine trade in South Africa incorporates the use of over 2000 indigenous plant species (Williams *et al.*, 2013). Alien plant species cited in various studies usually get little attention as they are simply listed as species used but no further analyses or investigations regarding these aliens are conducted (Mander, 1998a; Botha *et al.*, 2001; Grace, 2002). Therefore, this study fills a gap by recording which alien plant species are used for traditional medicine in South Africa. A literature review of 40 previous studies from various parts of South Africa was conducted in conjunction with surveys at the markets and shops in Johannesburg, Durban and Pretoria.

Inventories are valuable because they guide research towards useful plant species and indicate which species are threatened by over-exploitation (Grace, 2002; Grace *et al.*, 2003). Alien invasive plant species may threaten other indigenous species (Raimondo and von Staden, 2009). Therefore alien inventories are also valuable in that they highlight the sources, the volumes being sold, as well as provide a total of alien and indigenous plant species traded, indicating the size of the trade in these species.

3.2 Inventory methods

3.2.1 **Numbers of alien ethnomedicinal plant species**

An inventory detailing alien plant species sold in *muthi* markets and shops in Johannesburg, Durban and Pretoria was compiled. This inventory included the botanical name, English common name(s), vernacular name(s), invader status, plant part used of each species, country of origin, voucher number, and the frequency of occurrence in the various retail outlets (Appendix 4).

The terms ‘plant part’ in the inventory referred to the part of the plant being sold, e.g. bark, leaves, roots etc. Voucher specimens of most of the alien plants recorded in this study were purchased from the outlets and were preserved and lodged at the C.E. Moss Herbarium at the University of the Witwatersrand (J).

The invasive status of the alien plant species recorded are defined in Table 1.1 and include: Category 1 (Declared weed, prohibited and must be controlled); Category 2 (Declared invader – commercial and utility plants, allowed in demarcated areas by permit holders); Category 3 status (Declared invader – ornamentals, no new planting, trade or propagation is not permitted), and species whose categories differed according to geographical region, (‘multi-category) i.e. Category 1 and 3 (e.g. *Ipomoea alba* and *Ipomoea indica*).

A second inventory citing all alien plant species used and/sold for traditional medicine in South Africa was compiled. This inventory consisted of a review of 40 studies as well as information from this present study’s market and shop surveys in Johannesburg, Durban and Pretoria (Appendix 5). References used in the literature review are listed in Appendix 5.

Studies reviewed were sought in specific journals, such as ‘South African Journal of Botany’, ‘Economic Botany’, and ‘Bothalia’; in general, searches were conducted using ‘Google Scholar’ and reference lists from scientific papers. Thereafter, each species was checked to ensure the botanical name, family name and author were up to date, using POSA (Plants of Southern Africa) and SIBIS (Sanbi Integrated Biodiversity Information System) databases (http://posa.sanbi.org; http://sibis.sanbi.org). Some species were not listed on these databases and required further searching in other databases such as TROPICOS (http://www.tropicos.org) and (GISD) Global invasive Species Database (http://www.issg.org/database/welcome).

3.2.2 **Specimen identification of alien plant species in this study**

Most of the alien plants recorded in this study were identified during the Warwick market survey by Dr N.R Crouch. However four alien plants that were not initially identified to species include *Anredera cordifolia* (Ten.) Steenis, *Hedychium gardnerianum* Ker Gawl., *Opuntia robusta* H.L.Wendl. in Pfeiff. and *Opuntia ficus-indica* (L.) Mill. Samples of *A. cordifolia* and *H. gardnerianum* were both planted in order to identify them to species level. *Hedychium gardnerianum* was identified by its flowers, whereas *A. cordifolia, O. robusta* and *O. ficus-indica* were identified with the help of Ms Liame Van Der Westhuizen and Mrs Hildegard Klein from Agricultural Research Council, Plant Protection Research Institute) Weeds Division.

3.2.3 **Preparation of alien plants as voucher specimens**

Specimens were kept at 3ºC for 4 days to delay drying and wilting before preparation as voucher specimens. Most specimens were placed in a botanical press and oven-dried at 80 ºC (Cunningham, 2001). Two of the three *Bryophyllum* species were placed in boiling water and then the leaves were individually separated and spread out on a voucher specimen sheet. The same procedure was used for *Spilanthes mauritiana* (Pers.) DC., *Commelina benghalensis* L. and *Mimosa pudica* L. var. *hispida* since their leaves had already started drying.

The succulent cladodes *Opuntia robusta* and *O. ficus-indica* were prepared as voucher specimens by slicing them open longitudinally, removing the mucilage and spraying each half with 70% formaldehyde, after which the wet surfaces were exposed to direct sunlight for two hours (Reyes-Agüero *et al.*, 2007). Bark specimens were dried at 80 ºC for several days until they reached a constant mass (Williams *et al.*, 2005b.).

3.3 Results

3.3.1 **Numbers of alien ethnomedicinal plant species**

This study recorded 49 alien plants being sold, 26 species of which were recorded for the first time. Twelve of the 49 plants were not identified and are only known by their vernacular names (Figure 3.1; Appendix 4). Six out of the 49 alien plant species recorded in this study have invader status (Table 3.1).

The literature review recorded 320 alien ethnomedicinal plant species being used/sold in South Africa for traditional medicine (Appendix 5). Fifty-three of the 320 species (17%) have weed and/or invader status', and of these 27 species are in Category 1 (Declared weed), 16 species are in Category 2 (Declared), eight species are Category 3 (Declared invader), and two species have categories that differ according to geographical region including Category 1 and 3 (Table 3.1).



***dumapansi* (Z)**



***girmalasing* (I)**



***inderjow* (I)**



indian pearls; indian peanuts; indian beans (E)



***kachka* (I)**



***kamal kadi*; *kamal kachie* (I); *impitie* (Z)**



No photos available for:

- ***avalkadle* (I)**
- ***ibande* (Z)**
- ***inhlanhla emhlophe* (Z)**
- ***iphengula* (Z)**
- ***unukani oyikhambi* (Z)**

***kapoor kachi* (I)**

Figure 3.1. Unidentified alien plant species recorded in this study known only by vernacular name.

Based on the literature review of alien plants and recent work by Williams *et al.* (2013) there are at least 2382 indigenous and alien plant species used for traditional medicine in South Africa. This number is made up of 320 alien plant species and 2062 indigenous plant species (Table 3.2), hence 13.4% of medicinal plant species used in South Africa are aliens. Given that 53 of those alien species are invasive, only 2% of all the plant species traded in South Africa (2382) are invasive plant species.

Of the 320 alien plant species recorded in the literature review, 116 (36%) species have been recorded as being sold, whereas the other 64% were recorded as only being used (Table 3.2). The proportion of alien plant species sold and used is similar to the proportion of indigenous species that are used and sold as cited by Williams *et al.* (2013) (Table 3.2).

Table 3.1. Declared weeds and invasive plants of 53 alien ethnomedicinal plant species that are used/sold in South Africa (according to the Conservation of Agricultural Resources Act of 1983). These species were cited in 40 studies listed in the literature review, which were published between 1895 and 2011 (Appendix 5). Species in **bold** were recorded in this study.

Category 1 Declared weed	Category 2 Declared invader (commercial & utility plants)	Category 3 Declared invader (ornamentals)	Multi-category 1 and 3
Acacia pycnantha	*Acacia decurrens*	*Ailanthus altissima*	*Ipomoea alba*
Albizia lebbeck	*Acacia melanoxylon*	*Bauhinia variegata*	*Ipomoea indica*
Anredera cordifolia	*Agave sisalana*	*Eriobotrya japonica*	
Argemone mexicana	*Atriplex nummularia*	*Ipomoea purpurea*	
Argemone ochroleuca subsp. *ochroleuca*	*Casuarina equisetifolia*	*Melia azedarach*	
	Eucalyptus camaldulensis	*Mimosa pigra*	
Arundo donax	*Eucalyptus grandis*	*Phytolacca dioica*	
Bryophyllum delagoense	*Gleditsia triacanthos*	*Senna didymobotrya*	
Cestrum laevigatum	*Nasturtium officinale*		
Cinnamomum camphora	*Pinus roxburghii*		
Cirsium vulgare	*Populus canescens*		
Convolvulus arvensis	*Psidium guajava*		
Cytisus scoparius	***Ricinus communis* var. *communis***		
Datura ferox	*Robinia pseudoacacia*		
Datura inoxia	*Salix babylonica* var. *babylonica*		
Datura stramonium	*Sorghum halepense*		
Hedychium gardnerianum			
Lantana camara			
Nerium oleander			
Nicotiana glauca			
Opuntia ficus-indica			
Opuntia monacantha			
Paraserianthes lophantha subsp. *lophantha*			
Passiflora coerulea			
Passiflora suberosa			
Solanum mauritianum			
Tithonia diversifolia			
Xanthium spinosum			

Table 3.2. Number of alien and indigenous plant species used and sold for traditional medicine in South Africa. The alien plant species are recorded from the literature review, and the indigenous plant species were recorded by Williams *et al.* (2013).

Plant species	**Used**	**Sold**	**Total**
Alien	204	116	320 (13%)
Indigenous	1406	656	2062 (87%)
Total	1612 (68%)	774 (32%)	2382

3.3.2 **'Under-differentiation' of vernacular names**

'Under-differentiation' of vernacular names was observed at Warwick market where the vernacular name '*umvuthuza*' was used for three different *Bryophyllum* species. Unfortunately these three *Bryophyllum* plants were not identified to species. Traders mentioned that the differences between the *Bryophyllum* spp. were due to their source, i.e. KZN and Johannesburg, however the dissimilarity was actually because they were different species. Further under-differentiation occurred where two completely different species, vernacularly known as '*abangqongqozi*', which means 'to knock', were identified. These were *Araucaria heterophylla* (Salisb.) Franco and *Eleutherine bulbosa* (Mill.) Urb. and consisted of pieces of greenish-brown bark and bulbs approximately 3-5cm long respectively.

3.3.3 **Identification of previously unidentified species**

Prior to this study, *Acorus calamus*, *Helicteres isora* and *Glycyrrhiza glabra* were recorded in other studies as "unidentified species" and were referred to only by their vernacular names (*kalamusi/ukalamuzi; jikantambo/jigantambu;* and *umlolumnandi/mlomonandi* respectively) (Figure 3.2a, b and c) (Cunningham, 1988; Williams, 1992; Williams *et al.*, 2001; Loundou, 2008). With the aid of Von Ahlefeldt *et al.* (2003), *Acorus calamus* was identified since a similar vernacular name was listed in the book. *Helicteres isora* remained unidentified in various studies for several years (1988-2011) and was finally identified using "*Seed Album of Some Medicinal Plants of India*" by Joshi *et al.* (2005). *Glycyrrhiza glabra* was identified through a general internet search and in the process of finding exporters of Indian plants. Looking at other products Indian exporters traded, the following other species were identified: senna pods and leaves as *Cassia angustifolia*; '*hurle*' as *Terminalia chebula* and '*munyu/umunyu*' as *Withania somnifera* (Figure 3.2d, e, f and g). These three species were specifically sold by *muthi* shops.



a) *Acorus calamus* (*kalamusi)*



b) *Helicteres isora (jikantambo)*



c) *Glycyrrhiza glabra (mlomonandi)*



d) *Cassia angustifolia* (senna pods and leaves)



e) *Terminalia chebula (hurle* – small)



f) *Terminalia chebula (hurle* – large)



g). *Withania somnifera* (*munyu*/*umunyu)*

Figure 3.2. Species previously unidentified to a botanical name. Plants were only known by their vernacular name(s) prior to this study.

3.3.4 Number of alien ethnomedicinal plant species in different forms of outlets

Type of retail outlet selling alien species for traditional medicine

In the Johannesburg and Durban surveys, 26 alien plant species were recorded as being sold by 60 traders in both markets (Table 3.3), whereas 41 species were recorded in 17 shops in Johannesburg, Durban and Pretoria (Table 3.3). Six invasive plant species were sold at both markets, and shops sold five of the same invasive species that were sold at the markets (Table 3.4).

Race of retail outlet owner selling alien species for traditional medicine

Although similar numbers of traders were interviewed, Indian-owned shops sold more than twice the number of alien plants than shops owned by Black traditional healers (34 and 16 species respectively) (Table 3.3). Indian MS sold three invasive species, whereas Black-owned MS sold two invasive species that were different to those sold at Indian-owned shops (Table 3.4).

Region of retail outlet selling alien species for traditional medicine

Similar numbers of alien plant species were sold in Johannesburg and Durban, in the *muthi* markets and shops combined (33 and 37 species respectively) (Table 3.3). Johannesburg and

Durban outlets also sold similar invasive plant species, however, Johannesburg outlets sold one more invasive species compared to Durban outlets (6 and 4 respectively) (Table 3.4).

Table 3.3. Total number of alien plant species (S, species richness) recorded in the traditional medicine markets and *muthi* shops surveyed. Number of records (N) refers to the total number of.observations for all species combined recorded in all the outlets surveyed. .

Markets and *muthi* shops (MS) outlets	# Traders interviewed (n)	# records (N)	Species richness (S)
Markets			
Faraday	32	62	18
Warwick	28	82	22
Both markets	60	134	26
Muthi shop locality			
Jhb	10	59	26
Pretoria	4	30	18
Durban	3	40	28
All *muthi* shops	17	125	41
Muthi shop ownership			
Indian-owned	9	96	34
Black owned	8	34	16
Market and MS locality			
*All Jhb outlets	32	113	33
*All Durban outlets	28	123	37
All outlets combined	77	259	49

*Pretoria MS data not included.

Table 3.4. Invasive alien plant species sold at Faraday and Warwick traditional medicine markets and *muthi* shops (MS) in Johannesburg (JHB) and Durban (DBN).

Invasive species	Both markets	All MS	Indian-owned MS	Black-owned MS	JHB outlets	DBN outlets
Anredera cordifolia	✓	✓	✓		✓	✓
Bryophyllum delagoense	✓					
Cinnamomum camphora	✓	✓	✓		✓	✓
Hedychium gardnerianum	✓	✓	✓		✓	✓
Opuntia ficus-indica	✓	✓		✓	✓	✓
Ricinus communis	✓	✓		✓	✓	

3.3.5 **Alien plant species used by consumers of traditional medicine and other members of the public**

Thirty six (11%) of the 320 alien plant species recorded in the literature review were commonly used for other purposes besides traditional medicine (Table 3.5). These species are fruits, vegetables, nuts and herbs.

Table 3.5. Common culinary alien plant species that include fruits, vegetables, herbs and nuts that were encountered in the review. These alien species were not exclusively used by customers for traditional medicine.

Species name	Common name (s)
Allium cepa	Onion (E)
Allium sativum	Garlic (E)
Anacardium occidentale	Cashew (E)
Anethum graveolens	Dill (E)
Anthriscus sylvestris var. *sylvestris*	Cow parsley (E)
Apium graveolens	Celery (E)
Arachis hypogaea	Peanut; Groundnut; Monkeynut (E)
Beta vulgaris subsp. *vulgaris*	Beetroot (E)
Brassica rapa	Turnip; Sarson (E)
Carica papaya	Pawpaw; Papaya (Afr)
Citrus limon	Lemon (E)
Coriandrum sativum	Coriander (E)
Cydonia oblonga	Quince (E)
Daucus carota	Carrot (E)
Eriobotrya japonica	Loquat
Foeniculum vulgare	Fennel (E)
Helianthus annuus	Common sunflower (E)
Hypericum perforatum	Saint John's wort (E); Johanneskruid (Afr)
Ipomoea batatas	Sweet potato (E)
Macadamia sp.	Macadamia nut (E)
Mangifera indica	Mango (E)
Mentha spicata	Spearmint (E); Kruisement (Afr)
Nicotiana tabacum	Tobacco(E); Tabak (Afr)
Opuntia ficus-indica	Sweet prickly pear (E)
Passiflora edulis	Purple granadilla (E)
Persea americana var.	Avocardo (E)
Petroselinum crispum	Parsley (E); Pietersielie (Afr)
Physalis peruviana	Cape gooseberry (E); Appelliefie (Afr)
Prunus persica var. *persica*	Peach (E)
Psidium guajava	Guava (E); Apple guava (E); Koejawel (Afr)
Raphanus sativus	Radish (E)
Rosmarinus officinalis var.	Rosemary (E)
Salvia officinalis	Sage (E); Salie; Maksalie (Afr)
Sesamum orientale	Sesame (E)
Urtica dioica	Stinging nettle (E)
Zingiber officinale	Ginger (E); Gemmer (Afr)

3.4 Discussion

3.4.1 **Numbers of alien ethnomedicinal plant species**

Forty nine alien plant species were recorded as being sold for traditional medicine in this study, 26 of which were recorded for the first time. Although the largest *muthi* markets and many shops were surveyed, it remains likely that there are more alien plant species that are used for medicine that were not present, recorded and/or identified during the surveys.

The 49 alien plant species recorded in this study during the surveys only make up 15% of all 320 alien plant species recorded as being used in South Africa, indicating that the trade in alien species in Johannesburg, Durban and Pretoria only makes up a small portion of all the alien species traded for traditional medicine in South Africa. In addition, this means that if the usage of alien species should be controlled, Gauteng and KZN are not the only provinces that should be monitored.

The *muthi* trade was calculated to include 2386 alien and indigenous plant species with the alien plant species only making up 13% (Table 3.2). This indicates that the use of alien plant species only makes up a small percentage of the total traditional medicine trade.

The percentage of alien and indigenous plant species that are only recorded as being used for traditional medicine were much higher than the percent of alien and indigenous plant species that were sold (Table 3.2). This signifies that the use of traditional medicine spans across many more plant species than those observed and recorded at *muthi* markets or shops.

Seventeen percent (53 species) of all of the 320 alien plants species used/sold for traditional medicine (Table 3.2) as recorded in this study are invasive. This reasonably small percentage of invasive alien species suggests that there is a low chance of plants spreading through the *muthi* trade if the viability of these propagules is low. This is further explored in Chapter 4. This study in conjunction with the literature review recorded an additional 93 alien plant species used for traditional medicine compared to 227 alien plant species recorded by Arnold *et al.* (2002), who consolidated the information from 109 studies.

The use of alien plant species for traditional medicine has the potential to reduce the pressure on heavily harvested indigenous species, where they are used as a substitute. Information on

substitutes was very sparse, with only the following information found: bark imported from India, which include *Cinnamomum camphora*, *dumapansi* and *umLuthu*, have acted as a substitute for *Berchemia discolor* and *Ochna natalitia,* and Asian (Indian) MS traders often import alien species as substitutes for scarce indigenous species or as new medicines (Williams, 1992; Williams *et al.*, 2000). The root of *Acorus calamus* is another example of an alien species that is used instead of the bark of the highly threatened *Warburgia salutaris* (Cunningham, 1988; Cunningham, 1994).

3.4.2 **Numbers of alien ethnomedicinal plant species in different outlets**

Type of retail outlet selling alien species for traditional medicine

Muthi shops sell more alien species compared to markets. Furthermore, the shops sell a larger range of imported alien plant species (22 species) as well as a large range of naturalised alien plant species (19 species). This is compared to the markets that also sell a large variety of naturalised alien plant species (21 species) but a small range of imported species (5 species). These results are explained in more detail in chapter 6. The markets only sell a few popular imported species (i.e. species that are generally in higher demand and are sold more frequently). Market traders buy these imported species from Indian-owned shops, possibly because these outlets are more accessible to traders than wholesalers such as A.M. Khan.

Muthi shops sold more alien plant species compared to the markets because of the three factors: historical interactions between Indian and Black traders, source of the alien plant species (imported and naturalised) and race of customers. *Muthi* shop owners, specifically Indian owners, have a history of importing plant species from India (Cooppan, 2010), and are the only outlets that buy imported alien plant species from A.M. Khan Wholesalers. Khan wholesalers are situated in the Durban CBD and are major importers of plant species from India. There are two Khan Wholesalers, A.M and A.H. Khan Wholesalers, who run a family business and sell the same species. Traders often just refer to these wholesalers as ‘Khan’ or ‘Khan Wholesalers’.

Muthi shops in this study were found to also sell naturalised alien plants species, which were purchased from the markets and were predominantly harvested in KZN. Nesvåg (1999), reported that Indian-owned shops in Durban buy plant species from the Warwick market, and

Williams (2003) explains that *muthi* shops on the Witwatersrand (Gauteng) obtained 31% of their supplies from the Faraday market.

Consumers of traditional medicine are predominantly Black people, with the minority being Indian, Coloured and White (Nesvåg, 1999; S. Dorasammy pers. comm. 2011; A.M Khan pers. comm. 2011). *Muthi* shops and markets both function as retailers (selling to members of the public) and wholesalers (selling to other shops and market traders). Retail customers of *muthi* shops (especially Indian-owned) consists of approximately 70% Black and 30% Indian, White and Coloured customers (S. Dorasammy pers. comm. 2011; A.M Khan pers. comm. 2011), whereas markets as retailers have largely Black customers (Nesvåg, 1999), with this study observing that markets have a 99% Black customer base and 1% Indian, White and Coloured client base. *Muthi* shops as wholesalers (particularly Indian-owned) sell imported plant species to other Indian shop owners, market traders and Black shop owners (A.M Khan pers. comm. 2011). Lastly, markets as wholesalers sell naturalised alien plant species to Indian and Black shop owners (Williams, 2003; 2005a).

Race of retail outlet owner selling alien species for traditional medicine

Double the number of alien plant species are sold at Indian-owned *muthi* shops compared to Black-owned shops and the same reasons above apply: historical interactions between Indian and Black traders, source of the alien plant species (imported and naturalised) and race of customers. Black-owned shops were similar to the markets regarding the ethnic group of customers and proportion of imported and naturalised plant species. In this study it was found that Black-owned shops sell a higher percentage (63%) of naturalised alien plant species and a lower percent (37%) of imported alien plant species. In contrast, Indian-owned shops sell more imported alien plant species (64%) and fewer naturalised alien plant species (this is explained further in Chapter 6, Figure 6.1).

Indian and Black-owned shops sell fewer invasive alien species compared to the markets. Imported species sold by shops are not naturalised alien plant species and are thus not invasive as yet. The naturalised and invasive alien species that are sold in markets in this study were predominantly harvested from KZN. It was found that the invasive alien species that are traded in Indian and Black-owned shops are obtained from the markets.

Region of retail outlet selling alien species for traditional medicine

Comparing the cities, Durban sells a higher, but not significantly higher, number of alien species compared to Johannesburg. This difference is due to three factors: source of alien plant species sold; location of outlets (i.e. the Warwick market and Durban MS); and lastly the predominance of the South African Indian population in the Durban region. These factors are not independent, but are interlinked.

Of the Durban outlets which include Durban *muthi* shops and the Warwick market, it was observed that the source of alien species sold in Durban are mostly imported from India. Alien species sold at the Warwick market are mostly harvested in KZN. Alien plant species were introduced into South Africa from many other countries (Wells *et al.*, 1986; Henderson, 2006), but a probable reason as to why there are so many naturalised alien plant species in Durban is because of the Indian indentured labours planting species used for Indian TM in KZN (Cooppan, 2010).

The second factor that has caused the city of Durban to sell more alien plant species compared to Johannesburg is the location of the Durban shops and the Warwick market, which is KZN. KwaZulu-Natal is the province where the indentured labours immigrated to and where Indian muthi shops were first opened (Nesvåg, 1999; Flint, 2006). The last factor explains that there are currently 72% of South Africa's Indians living in KZN, (www.statssa.gov.za, 2012) inferring that there is a greater demand for Indian traditional medicine in Durban compared to Johannesburg. Lastly, Khan wholesalers are based in Durban and provide easy access to Indian-owned shops to purchase imported plant species.

The city of Durban sells only a few more alien plant species compared to Johannesburg, because almost all of the alien species sold in Durban are transported to Johannesburg. The alien plant species sold in Warwick are transported to the Faraday market in Johannesburg (Williams, 1992; Williams *et al.*, 2007a). In addition the *muthi* shops in Johannesburg and Pretoria obtain their imported alien plant species from the wholesaler in Durban or via other Indian shops.

The invasive plant species that are sold in Johannesburg and Durban outlets include: *Anredera cordifolia, Cinnamomum camphora, Hedychium gardnerianum, Opuntia ficus-*

indica. In addition, Johannesburg outlets sell *B. delagoense* and *Ricinus communis* var. *communis.* This study found that the *R. communis* seeds that are sold in Johannesburg outlets are sourced from KZN. This proves to be insightful, since this species is not sold at any Durban outlets, but is distributed in both Gauteng and KZN (Henderson, 2001a). This raises the question why *R. communis* is sourced from Durban when there are naturalised populations of the species occurring in Gauteng and KZN. A likely reason for why *R. communis* is only sold in Gauteng is because many Zulu speaking people from KZN currently reside in Johannesburg. This is indicated by Statistics South Africa (www.statssa.gov.za, 2013) reporting that Zulu is the most spoken language in Gauteng. This further indicates that even though *R. communis* is naturalized in Gauteng, these Zulu residents might not know of the populations in Gauteng and therefore buy it from either the Johannesburg shops or the Faraday market. It is proposed that it is because the species grows as a weed in the province and the users harvest it themselves from surrounding areas, resulting in no need for it to be sold in any *muthi* shops or markets in Durban.

3.4.3 **Alien plant species used by consumers of traditional medicine and other members of the public**

Eleven percent of the alien plant species recorded in the literature review are culinary foods or species that are commonly used by many South Africans. Most of these species have been in South Africa for decades (Alpern, 2008) and some of these species include: *Mangifera indica* (mango); *Daucus carota* (Carrot); *Allium cepa* (Onion) and *Rosmarinus officinalis* var. (Rosemary) (Table 3.5). In addition, another common alien species used by medicinal plant consumers and the public is *Coix lacryma-jobi*. The seeds of this species are commonly used as beads in jewellery items (Figure 3.3). It is interesting that most of society merely uses these culinary species for nutrition, while consumers of *muthi* use these species for medicinal purposes.



Figure 3.3. Alien plant species, *Coix lacryma-jobi,* recorded at used for traditional medicine but also used commonly in jewellery items and rosaries.

3.5 Conclusion

This study found that 320 alien plant species are used for traditional medicine in South Africa, 17% of which are invasive alien species derived from CARA. The invasive alien species recorded as being sold includ: *A. cordifolia, Bryophyllum delagoense, C. camphora, H. gardnerianum, O. ficus-indica* and *R. communis* var. *communis.* Even though such a small percent (17%) of invasive alien species are sold, this alone does not suggest that there is a low chance of these invasive species becoming an increased problem because of the *muthi* trade. Other factors such as the volume of the species traded and the viability of their propagules can largely influence their ability to spread further through the trade.

The trade in both alien and indigenous plant species is extensive, totalling over 2300 plant species. Of the total number of indigenous and alien plant species that are used for traditional medicine in South Africa, the trade in alien plant species only makes up a small proportion. This information is useful for conservationists as they are concerned with the protection of indigenous species that may be threatened due to the trade of alien species for medicine. This study's results on the potential spreading of alien plant species through the South African *muthi* trade will be valuable to alien plant specialists.

The use of alien plant species helps reduce pressure on heavily traded indigenous plant species, and further research in this regard will be useful. The difference in the number of alien plant species sold in various outlets is not merely due to coincidence but is as a result of a two factors. These factors include: the importation of plant species from India in the past

and in the present time and the percentage of Indian and Black customers buying alien plant species from Indian and Black-owned MS.

The fact that alien plant species are used and sold for TM in South Africa may come as a surprise to many. However it shouldn't, as not only are alien plant species used by customers of traditional medicine, but most members of the public make use of alien plant species in their daily lives.

CHAPTER 4: VIABILITY OF ALIEN PLANT SPECIES RECORDED IN THIS STUDY

4.1 Introduction

Plant species sold in the *muthi* trade are very often not sold as whole plants, but as plant parts (Mander *et al.*, 2007). A plant part refers to a section of a plant, including either the bark, roots or stem, which combined with all the parts makes up an entire plant. Plant parts include: bulbs, seeds, bark, roots, leaves, fruit, tubers, stems and whole plants (Van Wyk *et al.*, 1997; Van Wyk and Gericke, 2003; Mander *et al.*, 2007). Depending on the plant part harvested, the remainder of the plant may be negatively affected or the plant part harvested may be a reproductive part and if planted can cause the species to regrow vegetatively and spread (Cunningham, 1988; Williams *et al.*, 2000).

Depending on the plant part harvested and the severtity of the removal, some indigenous species are negatively affected by harvesting (Williams *et al.*, 2000)(Cunningham, 2001). Sever harvesting may cause the original plant to die and it has been shown that over 80% of indigenous plant species harvested in South Africa will result in the individual plant dying (Mander *et al.*, 2007). Since the trade of alien plant species has not been thoroughly recorded prior to this study, it is yet to be determined whether the trade in alien plant species has a negative effect on plant survival causing the existing alien plant species to die. Or, more importantly, if it promotes the growth and spread of alien species in South Africa. This issue will be explored in this chapter by examining of alien plant parts sold in the *muthi* trade.

4.2 Plant viability methods

4.2.1 **Plant parts of alien species recorded in this study**

In this study the number and percentage of alien plant species and their respective plant parts were counted. In addition, the plant part that was sold most often was determined.

4.2.2 **Viability of propagules**

Prior to the viability experiments, the propagules and seeds of alien species purchased during the surveys in this study were stored in brown paper bags. These bags were kept under

ambient conditions in a cool, dry place, out of direct sunlight in a laboratory at the University of the Witwatersrand.

To determine the viability of plant parts, 15 alien species sold as propagules in the markets were planted. One of the species, *Helicteres isora*, has a fruit that unwinds under hot conditions and releases its seed (Joshi *et al.*, 2005). The propagules of this species were thus planted in three different ways: whole fruit, manually unwounded fruit with seeds still attached, and only seeds that had been removed from the fruit after heating.

Propagules were planted in potting soil in 250ml polystyrene cups in a greenhouse at the University of the Witwatersrand (Figure 4.1). The temperature and humidity were on average 30ºC and 70% respectively and the specimens were watered twice daily. Of the alien plant species purchased during the surveys in the study, a subset of each sample was used either for propagating, tetrazolium testing or for reference material.

Specimens used for the tetrazolium tests were, cut longitudinally and then placed in individual petri dishes. Tetrazolium solution was prepared by using 1% P-buffered solution of 2.3.5-triphenyl tetrazolium chloride. Specimens were then incubated in the solution at 30ºC for 24hours in a dark cupboard (Savonen, 1999).

a) b)



Figure 4.1: Seeds of (a) *Brassica* sp. (mustard) and (b) *Ricinus communis* var. *communis* that were planted and sprouted.

4.3 Results

4.3.1 **Plant parts of alien species sold in this study**

Seeds, bark and succulent stems were the most common plant parts sold at all the outlets (Table 4.1). The invasive species sold in this study were sold in the same form, but also as rhizomes and tubers (Table 4.1). *Ricinus communis* seeds were sold by eight traders in the form of oil called Castor oil (Table 4.1).

Table 4.1. Plant parts of alien plant species sold for use in traditional medicine in this study. Six invasive species are listed against their respective plant parts.

Plant part	**Number and % of all alien species**	**Invasive alien species sold**
seeds	12 (25)	*Ricinus communis* var. *communis**
bark	7 (15)	*Cinnamomum camphora*
succulent stem	6 (13)	*Bryophyllum delagoense*, *Opuntia ficus-indica*
seed pods	5 (11)	
rhizome	3 (6)	*Hedychium gardnerianum*
tuber	2 (4)	*Anredera cordifolia*
leaves and stems	4 (8)	
roots	3 (6)	
nuts	2 (4)	
galls	1 (2)	
stems	1 (2)	
whole plant	1 (2)	
bulb	1 (2)	
unidentified part	1 (2)	
Total	49	

* *Ricinus communis* was recorded eight times being sold as oil.

4.3.2 **Viability of propagules from this study**

Out of the 21 species tested (17 named species and kamal kachi, Indian pearls, *girmalasing* and *inderjow*) for germination, 10 species sprouted (Table 4.2). In addition, tetrazolium tests conducted on 11 species showed that 8 species were viable, but only 7 species were viable above 50% (Table 4.2; Figure 4.2). *Anredera cordifolia* and *H. gardnerianum* both sprouted 100%. *Ricinus communis* showed only 35% germination. The seeds of *R.* were, however, found to be 65% viable as indicated by the tetrazolium tests (Table 4.2).

Cladodes of *O. ficus-indica* were not planted, however roots developed on the cladodes indicating that the species would have grown if given the opportunity. *Bryophyllum delagoense* was sold as a whole plant and therefore was also not planted, but would have

grown having roots, stems and leaves still intact. *Cinnamomum camphora* was sold in the form of bark and would not have sprouted or germinated.

Type of retail outlet and propagule viability

Traditional medicine markets sold more alien species that had over 50% viability compared to *muthi* shops (Table 4.2 and Table 4.3). Nonetheless, out of all the alien plants species sold at the markets and shops, only 30% of the total species sold at each outlet had over 50% viability (Table 4.3). In addition, markets sold one more invasive alien plant species compared to shops which included *B. delagoense.*

A few of the traders at Warwick and Faraday mentioned that they or their customers either grew certain species themselves, had them growing in their neighbourhood or that they grew easily. Species that were reported to grow easily included: *Acorus calamus, Coix lacryma-jobi, Foeniculum vulgare, Hedychium gardnerianum, Opuntia ficus-indica, O. robusta, Pedilanthus tithymaloides* subsp. *smallii,* and *Ricinus communis* var. *communis.* Contrary to this, *C. camphora* and *Melaleuca leucadendron* were considered not easy to find or harvest due to these species generally being on private property. Traders often did not want to mention where they obtained these species from as they were worried that they would get into trouble with the authorities.

Race of retail outlet owner and propagule viability

Fifty percent of the propagules tested for viability that were sold at Indian and Black-owned shops, had over 50% viability (Table 4.3). However, out of all the alien species sold at both Indian and Black-owned shops, only 25% were viable (Table 4.3).

Region of retail outlet and propagule viability

Johannesburg outlets sold double the number of viable alien plant species compared to Durban outlets, indicated by 36% and 16% viability respectively. The viable invasive alien species sold at Johannesburg outlets included: *A. cordifolia, B. delagoense, H. gardnerianum* and *O. ficus-indica.* Durban outlets also sold the following viable invasive species: *A. cordifolia, H. gardnerianum* and *O. ficus-indica.*

Table 4.2. Viability of alien plant species sold for traditional medicine. Viability was tested by planting plant propagules and conducting tetrazolium tests, with 'n' representing the number of propagules tested. Species in **bold** are classified as invasive species in this study. Table also indicates which species were sold in various traditional medicine outlets.

Botanical name	Type of propagule	Viability Test		Outlets					
		Planted Emergence % (n)	Tetrazolium Stained % (n)	Both markets	All MS	Indian-owned MS	Black-owned MS	JHB outlets	DBN outlets
Acorus calamus	rhizome	0 (5)	-	✓	✓	✓	✓	✓	✓
Anacardium occidentale	seeds	43 (7)	86 (7)		✓	✓		✓	
Anredera cordifolia	**tuber**	100 (5)	-	✓	✓	✓		✓	✓
Brassica sp.	seeds	90 (20)	80 (20)		✓	✓		✓	
Cassia angustifolia	seed pods	50 (20)	44 (16)		✓	✓	✓	✓	✓
Coix lacryma-jobi	seeds	0 (20)	62 (13)	✓	✓		✓	✓	✓
Coriandrum sativum	seeds	-	75 (20)		✓	✓		✓	
Curcuma longa	roots	0 (10)	-		✓	✓		✓	✓
Eleutherine bulbosa	bulb	60 (5)	-	✓	✓	✓		✓	✓
Foeniculum vulgare	seeds	50 (20)	70 (20)	✓	✓	✓	✓	✓	✓
Girmalasing	seed pods	0 (20)	-		✓	✓		✓	✓
Hedychium gardnerianum	**rhizome**	100 (2)	-	✓	✓	✓		✓	✓
Helicteres isora	fruit	-	10 (20)	✓	✓	✓	✓	✓	✓
Inderjow	seeds	0 (20)	-		✓	✓		✓	✓
Indian pearls	seeds	0 (20)	-		✓	✓	✓	✓	✓
Kamal kachi	seeds	0 (20)	-		✓	✓		✓	✓
Macadamia sp.	nut	-	100 (11)	✓				✓	
Pedilanthus tithymaloides	succulent stems	100 (3)	-	✓				✓	
Ricinus communis* var. *communis	**seeds**	35 (20)	65 (20)	✓	✓		✓	✓	
Senna sp.	seed pods	40 (20)	-		✓		✓	✓	
Terminalia chebula (big seed)	seeds	0 (10)	0 (9)		✓	✓		✓	✓
Terminalia chebula (small seed)	seeds	0 (20)	0 (10)		✓	✓		✓	✓

Table 4.3. The number of viable and invasive alien species sold for traditional medicine at various retail outlets in South Africa.

Number of species	Both markets	All MS	Indian-owned MS	Black-owned MS	JHB outlets	DBN outlets	All outlets
Total species sold at outlet	26	41	34	16	33	37	49
Tested for viability	10	19	16	8	21	14	21
Viable	9	14	10	6	14	8	14
> 50% viability (emergence & tetrazolium tests)	8	12	8	4	12	6	12
% of species tested that had over 50% viability	80%	63%	50%	50%	57%	43%	57%
Percent viable from total # of species sold at outlet	31%	29%	24%	25%	36%	16%	24%
Viable invasives	3	3	2	1	3	2	3
Other invasive species (not tested for viability)	3*	2*	1*	1	2	2*	3*
Total invasive species	6	5	3	2	5	4	6

* includes pieces of *Cinnamomum camphora* bark,which are not capable of resprouting.



Figure 4.2. Tetrazolium staining of two species, *Macadamia* sp. and *Anacardium occidentale.*

4.4 Discussion

4.4.1 **Plant parts of alien species recorded in this study**

The plant parts that were sold most commonly in this study included seeds, bark, succulent stems and seed pods. Excluding bark, these plant parts generally germinate and sprout relatively easily. This is in contrast to the trade of indigenous plant species, where roots and bark are the plant parts that are most traded, (Williams *et al.*, 2001), and seeds only make up 1% of the plant parts sold (Williams *et al.*, 2001). Seventy five percent of the alien species

sold in this study were in the form of reproductive parts, namely seeds, bulbs, succulent stems, seed pods, tubers and rhizomes (derived from Table 4.1). Since the three most common plant parts and a large proportion of all the species sold in this study were in the form of plant parts that germinate easily, this indicates their potential to spread. In addition, the invasive alien species sold in this study were all plant parts that also germinate or sprout easily, excluding one species that was sold in the form of bark. Therefore five invasive species, namely *A. cordifolia, B. delagoense, H. gardnerianum, O. ficus-indica* and *R. communis* var. *communis* have the potential to spread as a result of the *muthi* trade.

Plant species that are sold in the *muthi* trade are used for medicinal, spiritual, cultural and cosmetic purposes (Dold and Cocks, 2005). Therefore users of traditional medicine do not specifically purchase species to plant them in the ground. However, as observed in this study, there was a small percentage (10%) of traders and customers that mentioned that they grew some of the alien species in their own gardens. In addition to traders or customers purposefully planting some alien species, there is also a possibility that a species can 'escape'. An 'escapee' refers to a propagule that falls to the ground while being transported. The likelihood of these two situations, purposeful planting and propagules 'escaping', are minimal but possible.

Species that are purposefully planted or are escapees have a very low chance of establishing and becoming invasive. This is explained by the "tens rule" that states that approximately 10% of all imported species will escape into the environment and become naturalised and 10% of the naturalised species will prove to become pests or invasive (Williamson *et al.*, 1986; Lockwood *et al.*, 2001; Hulme, 2003). Therefore, since 36 alien species are imported from India (with 12 being imported and also harvested in South Africa) and are not yet invasive in South Africa, according to the "tens rule", only 0.36 species sold for *muthi* recorded in this study may become established and invasive.

This study found for the majority, that the reproductive parts of alien species were mostly sold. The same result was found by Narasimhan (1999), who conducted a study in India on the medicinal plant species sold at the Chennai Raw Drug market in Tamil Nadu (India). Narasimhan (1999) found that 80% of the plants sold were for their reproductive parts and their roots. This indicates that there is a similarity between the plant parts of species sold in

this study and plant parts sold in Tamil Nadu, India. A possible reason for the similarity between alien plant species in this study and plant species sold for medicine in India is because many of the alien plant species sold in this study are either currently imported from India or were imported and planted by the mainly Tamil-speaking Indians who immigrated to KZN in the 1860s (Flint, 2006).

A large proportion of reproductive parts of plant species are used for medicine in India and this phenomenon is due to beliefs from the Ayurveda, Siddha and Unani medicinal systems (Narasimhan *et al.*, 1999). Other pharmaceutical industries in India also demand seeds, roots and underground propagules as they consist of higher concentrations of pharmacologically active compounds, more than those in vegetative parts (Narasimhan *et al.*, 1999).

The trade in alien plant species differs from that of the indigenous species traded in South Africa. This is because a large proportion of the indigenous species are sold in the form of vegetative parts, which is opposite to the large proportion of reproductive parts in the case of alien species. Unfortunately, harvesting vegetative parts results in the individuals of many indigenous plant species dying (Cunningham, 1991; Williams *et al.*, 2000; Cunningham, 2001; Williams *et al.*, 2001; Mander *et al.*, 2007). The trade of alien plant species on the other hand may not result in death of the mother plants but rather their potential to spread.

The trade of plant species has varying effects depending on the plant part harvested. The removal of roots, bulbs, whole plants and bark has a more immediate and damaging effect than the harvesting of leaves and fruit (Cunningham, 1988; Williams *et al.*, 2000). Harvesting of whole plants and roots more often than not results in plant mortality. If the entire root is removed before the plant has produced seeds, this effectively ends the likelihood of future growth and regeneration of that individual (Sheldon *et al.*, 1997; Williams *et al.*, 2000). Roots that are only partially removed are affected by a reduction in their ability to take up water, increasing their susceptibility to get fungal diseases, which can lead to mortality. Bark removal is not always detrimental to trees; however, ring-barking potentially inhibits long-term growth and/or reproductive fitness, ultimately causing plant death (Sheldon *et al.*, 1997; Williams *et al.*, 2000). Certain species are resilient towards extensive and persistent bark removal, whereas others are not (Sheldon *et al.*, 1997; Williams *et al.*, 2000). Therefore,

harvesting can promote mortality, inhibit growth and prolong the time taken to reach critical life stages, or have no discernible adverse consequences (Williams *et al.*, 2000).

Generally, harvesting of plant parts for traditional medicine is unsustainable due to vegetative parts of indigenous species being traded, stocks declining and distances to stocks increasing (Mander, 1998a). However, since the majority of alien plant parts sold consist of seeds, bulbs, succulent stems, seed pods, tubers and rhizomes, which are mostly reproductive parts, it appears that the harvesting of alien plant species is not detrimental to the growth and reproductive fitness of alien species, but may rather aid their spread in South Africa.

4.4.2 **Viability of propagules from this study**

Twenty four percent (12 species out of 49) of the species sold in this study were viable, indicated by the germination experiments and tetrazolium tests (Table 4.3). Included in this 24% were five invasive species, *A. cordifolia, B. delagoense, H. gardnerianum, O. ficus-indica* and *R. communis* var. *communis*, which sprouted easily, or would have sprouted easily if planted, in the case of *B. delagoense* and *O. ficus-indica.*

The invasive species in this study proved to be viable and traders also mentioned that some of them grew easily, which suggests that they have grown them (or witnessed them growing). This also means that these invasive species will most definitely be spread intentionally around South Africa. Fortunately *R. communis* was often sold in the form of oil, and seldom as seeds. Naturalised alien species sold in this study are harvested in KZN, Eastern Cape, Free State, Gauteng, Limpopo, Mpumalanga, Mozambique, Zimbabwe and India. Having knowledge of where alien species are harvested from and where they are transported to, gives a better understanding of the possible areas where invasive plant species may spread to or where alien species could become established.

Plant products sold at *muthi* markets often undergo a loss of moisture due to being stocked in the markets for long periods. These periods can range from a few days to several months before the product is sold (Williams *et al.*, 2007a; Wojtasik, 2009). This study found that the same applied to plant products sold at shops. The age of plants in the market could affect the viability of the alien plant species recorded in this study. Furthermore, the longer plant products are stocked in the market or shops, the less likely it is that any particular species would grow or germinate. Hong and Ellis (1996) Tang *et al.* (1999) explain that, during

storage, all seeds experience deterioration with the rate dependant on seed moisture, storage temperatures and the species. Tang *et al.* (1999) further explains that the rate of seed deterioration is lower where seeds are in environments that have lower moisture contents and lower temperatures, and by implication the opposite applies too. This further indicates that many of the propagules stocked in the markets most probably experienced deterioration because many plant products are laid out in the sun to dry and are often stored or stacked on a pile kept outside in the sun.

Type of retail outlet and propagule viability

Traditional medicine markets sold the most number of viable alien species as well as the highest number of invasive plant species (Table 4.3). Markets sold the highest number of viable species because it was observed that a large proportion of the species were harvested from the veld in KZN and were still fresh. On the other hand, exporters of Indian plants explain that some exported species, such as *Curcuma longa* (Turmeric sticks) and *Terminalia chebula* (*Hurle*) are dried hard before they are exported (www.sssbiotic.com; www.weiku.com). Since some of the imported Indian species are dried, this means that they will not germinate, reducing their chances of growing in South Africa and explaining their zero % viability (Table 4.2). Therefore it appears that the *muthi* markets may be the outlet that sells the most viable alien species and has the potential to cause more alien plant species to become established compared to *muthi* shops.

Race of retail outlet owner and propagule viability

Black-owned *muthi* shops sold slightly lower numbers of viable species compared to Indian-owned shops. However, 25% of all the species traded in Indian and Black-owned shops were viable (Table 4.3). This indicates that both Indian and Black-owned shops may have an equal chance in spreading viable alien plant species in South Africa and that one in every four traded alien plant species, is viable.

Region of retail outlet and propagule viability

Johannesburg outlets sold more viable alien plant species compared to Durban outlets, indicating that one in every three alien species sold for traditional medicine in Johannesburg

are viable. The reason for this difference could be because Durban outlets sold more imported alien plant species, which are usually dried before they are exported from India. This means that these imported species do not have a chance of growing or becoming established in South Africa.

4.5 Conclusion

This study found that 75% of all of the alien plant species sold in *muthi* markets and shops in Johannesburg, Durban and Pretoria were reproductive parts which have a chance of growing if given the opportunity (Table 4.1). Even though a large percentage of plant parts were reproductive parts, only 24% of all the alien species recorded in this study were viable, indicating that between 2-3 in every 10 alien species sold are viable and may possibly become established and invasive. This study found that five of the six alien species classified as invasive are sold as viable propagules. Considering the "tens rule", it appears that only 0.36 additional alien plant species may become established and invasive due to the whole traditional medicine trade. Alien plant species are transported to Johannesburg and Durban, indicating that the traded alien plant species may become established anywhere along the way.

Amongst the retail outlets, markets were found to have the greatest potential in helping causing alien plant species to become invasive. This is because the markets sell the most viable alien plant species compared to any other outlet. Similarly, Johannesburg compared to Durban is the region found to sell the largest number of viable alien species.

CHAPTER 5: VOLUME OF ALIEN PLANT SPECIES RECORDED IN THIS STUDY

5.1 Introduction

Traditional medicine is used by at least 27 million consumers in South Africa, with the *muthi* trade contributing to an estimated R2.9 billion to the national economy (Mander *et al.*, 2007). Annually 35000–70000 tons of indigenous plant material is consumed in South Africa, 4000 of which is sold in KZN (Mander, 1998; Mander *et al.*, 2007). The demand for traditional medicine is very high and currently there are numerous plant species which are in such high demand that they exceed the supply with traders stating that there are acute shortages and price increases (Mander, 1998a; Williams *et al.*, 2000; Williams *et al.*, 2005a).

Plant products sold at markets and some *muthi* shops are stocked in either 50kg bags (Figure 5.1a), piled in heaps (Figure 5.1b and c), or on shelves (Figure 5.1d). Furthermore, some plant species are chopped up (Figure 5.1e), crushed into a powder (Figure 5.1f), still whole (whole plant parts) (Figure 5.1g), packaged into bundles (Figure 5.1h), in small transparent packets (Figure 5.1i), sold on a string (Figure 5.1j), or kept in jars or bottles (Figure 5.1k). When any plant product is purchased, it is placed into a plastic packet (Figure 5.1l) or wrapped in newspaper. Plant products sold at the markets are not sold according to a specific mass but generally according to ‘handful’ volumes that are sold at a set unit price of R10 (Williams *et al.*, 2007a). Bundles of plant products are also sold at the same set unit price. The volume of alien plant species sold for traditional medicine is unknown, therefore this study aimed to quantify the volumes of alien plant species sold in Johannesburg, Durban and Pretoria at the time of the study (2011).



a)



b)



c)



d)



e)



f)



g)



h)



i)



j)



k)



l)

Figure 5.1. ‘Units’ in which plant products are stored in at a traditional medicine market. a) 50kg size bag, b) and c) plants heaped up, d) plant species stored on shelves, e) chopped up, f) crushed up, g) whole plant parts, h) bundles, i) small transparent packet j) plant species sold on a string, k) jars and bottles l) and blue packet.

5.2 Methods to quantify the volume of plant parts recorded in this study

In order to determine the overall volume of alien species sold in the *muthi* markets and shops, visual estimations of the volumes held by each interviewed trader were made in terms of 50kg-size bags (maize bag). Where visual estimations of volumes present were not possible, the results were based on the interviewee's response to the questionnaire. Estimations were made because it was impractical to weigh the quantity of each alien species present at the stall of every trader (Cunningham, 1988; Williams *et al.*, 2007a). For some species that did not quite fill a 50kg-size bag, the results were presented as a percentage of a 50kg-size bag.

For 18% of the alien species, the estimated volumes were not recorded during the interview because of practical reasons such as limited time at each trader. These were estimated during the analysis by assigning an average volume based on information that was gathered on that same species from other traders where volumes were recorded. Finally, these volumes were used to calculate the total volume of alien plant material that was present during the surveys in the markets and MS, at a snap-shot in time.

5.3 Results to quantify the volume of plant parts recorded in this study

Seeds, roots, bark and seed pods were the plant parts of alien plant species that were sold in the largest quantities, i.e. the largest number of 50kg-size bags. On the other hand, tubers, nuts, bulbs and whole alien plants were the plant parts that were sold in the lowest volumes (Figure 5.2). Twelve alien species were found traded in the form of seeds, whereas only one whole alien plant species was sold in the outlets.

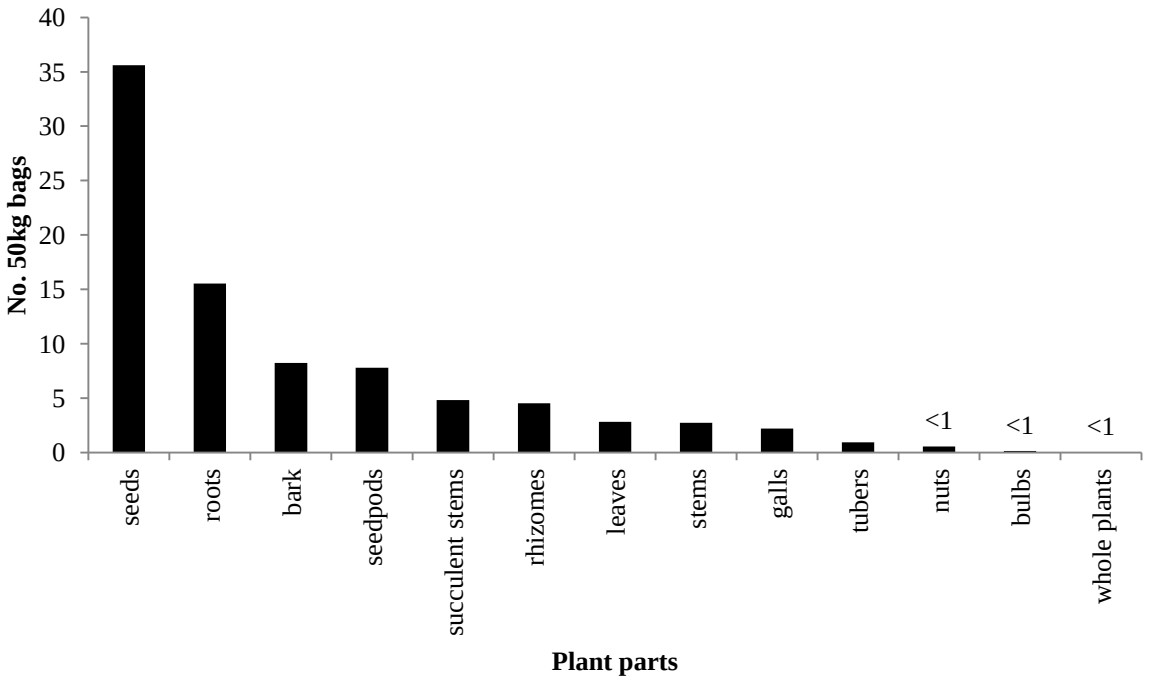


Figure 5.2. Estimated volumes of all the alien plant parts recorded in this study. Volumes were measured in 50kg-size bags.

The total volume of alien plant species recorded in this study was 87 x 50kg-size bags (Figure 5.3, Figure 5.4 and Table 5.1). *Kamal kadi*, *Brassica* sp. (mustard seeds), *C. longa* (turmeric sticks), *Cassia angustifolia*, and *T. chebula*, were the species that were present in the largest volumes in this study (Figure 5.3). *Kamal kadi* is the vernacular name for black oval shaped seeds and could unfortunately not be indentified to any taxonomic level. All of these five species were only sold in *muthi* shops. Four out of these five species were sold in the form of seeds or seedpods (Table 5.1). In contrast some of the species sold in the smallest volumes were: *Macadamia* sp., *iphengula*, *Mimosa pudica* var., *Platycarpha* sp. and *Sansevieria fasciata* (Table 5.2). The six invasive species that were recorded in this whole study, were recorded in small volumes, only filling up the equivalent 5-60% of a 50kg-bag, with the exception of *Opuntia ficus-indica* filling up 1 x 50kg-bag (Table 5.3).

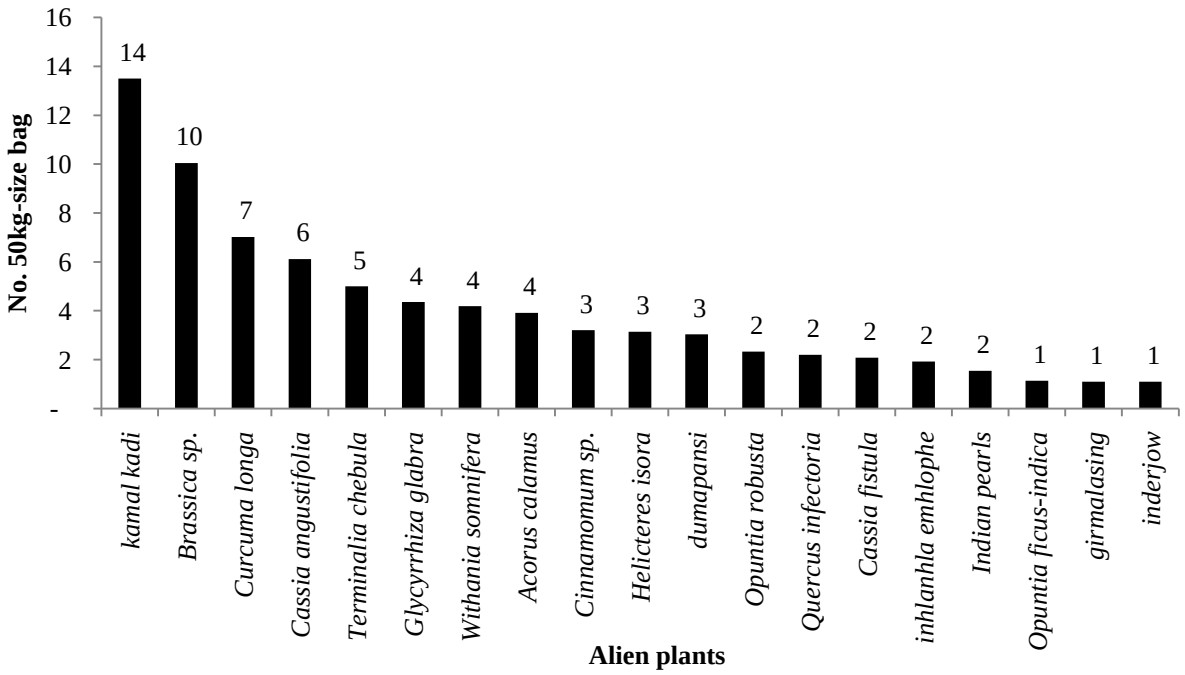


Figure 5.3. Estimated volume of alien plants that fill up whole 50kg-size bags. Subtotal equals 77 x 50kg-size bags.

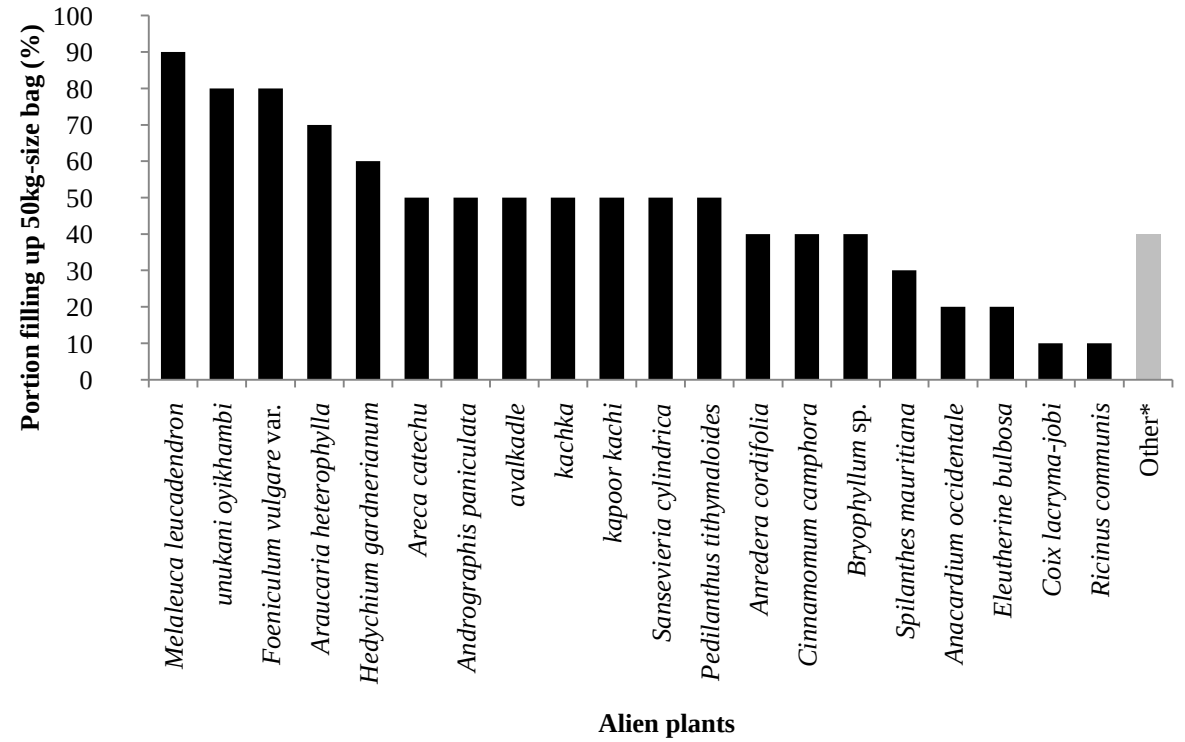


Figure 5.4. Estimated volume of alien plants that fill a proportion of a 50kg-size bag. (This is a continuation of Figure 5.3 above.) *These are comprised of 10 alien plants that are sold in small quantities. Refer to Table 5.3.

Table 5.1. Outlets and plant parts of five alien plants that were present in the largest volumes in three *muthi* shops (MS) in this study.

Alien plants	MS or market	Plant part	No. 50kg bags
kamal kadi	MS	seeds	14
Brassica sp.	MS	seeds	10
Curcuma longa	MS	roots	7
Cassia angustifolia	MS	seedpod & leaves	6
Terminalia chebula	MS	seeds	5

Table 5.2. Alien plants that were sold in small quantities in Faraday and Warwick markets and Johannesburg Durban and Pretoria *muthi* shops. Quantities add up to a total of 40% of a 50kg-size bag.

Alien plants	MS or market	Plant part	Portion filling a 50kg-size bag
Bryophyllum delagoense	Market	succulent stem	5%
Commelina benghalensis	MS	leaves and stems	4%
Coriandrum sativum	MS	seeds	6%
ibande	MS	bark	5%
iphengula	Market	rhizome	4%
Macadamia sp.	Market	nut	4%
Mimosa pudica var.	MS	leaves and stems	2%
Platycarpha sp.	MS	Whole plant	2%
Sansevieria fasciata	Market	succulent stem	2%
Senna sp.	MS	seedpod	5%

Table 5.3. Volume of invasive species sold in 50kg-size bags as recorded in both Faraday and Warwick markets and *muthi* shops in Johannesburg, Durban and Pretoria in this study.

Species name	MS or market	Plant part	Percent of 50kg-size bag
Anredera cordifolia	MS and Market	tuber	40
Bryophyllum delagoense	Market	succulent stem	5
Cinnamomum camphora	MS and Market	bark	40
Hedychium gardnerianum	MS and Market	rhizome	60
Opuntia ficus-indica	MS and Market	succulent stem	100
Ricinus communis	MS and Market	seed	10

5.4 Discussion to the volume of plant parts recorded in this study

The total volume of alien plant species recorded in the *muthi* markets and shops in this study was 87 x 50kg-size bags during the time of the survey (October 2010 – February 2011). An estimated 209 x 50kg-size bags of alien plant species would be sold on an annual basis in the traditional medicine trade in Johannesburg, Durban and Pretoria. In contrast to the volume of alien plant species recorded in this study, the trade in indigenous plant material in Faraday market alone in 2001 (Williams, 2003) was 14 times greater, measuring 1227 x 50kg-size

bags. This indicates that the trade in alien plant species in Johannesburg, Durban and Pretoria is almost trivial in comparison to the trade in indigenous plant species.

Approximately 44 x 50kg bags of seeds and seedpods of alien plant species were recorded in this study (Figure 5.2). These plant parts make up 51% of the total volume of alien plant species that were for sale during the time of the survey. The percentage of seeds and seedpods sold were much larger in comparison to only 0.04% of indigenous seeds that were sold in the Faraday market in 2001 (Williams, 2003). This highlights that the trade in alien species is predominantly based on reproductive plant parts. It cannot be concluded whether the trade in alien plant species has increased or decreased over the years due to this study being the first to measure this sector of the trade.

Of the five species that were sold in the largest volumes, four of them were in the form of seeds and seedpods, and one as roots (*Curcuma longa*). Kamal kachi and *Brassica* sp. (both sold in the form of seeds) had a total of 14 and 10 x 50kg bags present at various outlets within this study respectively. These volumes are very close to the volumes of two indigenous plant species (*Helichrysum* spp. and *Drimia* spp.) that were present in the largest volumes (16 and 11 x 50kg-size bags respectively) in 50 *muthi* shops in the Witwatersrand and 100 Faraday market traders surveyed in 1994 in 2001 respectively (Williams *et al.*, 2007a). The volume of plant species sold is driven by demand (Botha *et al.*, 2007; Williams *et al.*, 2007a). Therefore, even though the trade in alien plant species is only a fraction of the indigenous plant species traded, several alien plant species are sold in high volumes due to them being in high demand. Furthermore, even though not all the alien species recorded in this study are sold in large volumes, the fact that many alien species have been recorded in other studies (Cunningham, 1988; Hutchings *et al.*, 1996; Dold and Cocks, 2000; Lewu and Afolayan, 2009) and then again in this study, indicates that there is still a demand for alien plant species for traditional medicine.

Kamal kadi was the alien plant from India which was present in the largest volume in Johannesburg, Durban and Pretoria. All five alien species that were present in the largest volumes were only present in shops (Table 5.1). In addition, an informed Indian shop owner indicated that 40% of plants sold in his business are sold to Indian, White and Coloured customers, while the remainder is sold to Black customers. This corresponds to the fact that

C. longa, C. angustifolia, T. chebula and Brassica sp. are used for medicine in India (Joshi *et al.*, 2005; Dev, 2012). The supply for these alien species that are traded in high volumes are thus driven mainly by Indian customers. Even though these species are not invasive in South Africa, two of the species were viable, including C. *angustifolia* (senna pods and leaves) and *Brassica* sp. (mustard seeds). Therefore since these two species are sold in such large volumes and are viable, the Early Detection and Rapid Response Unit at SANBI should be aware of their trade as they may have the potential to spread.

5.5 Conclusion

The volume of alien plant species sold for traditional medicine as calculated in this study amounted 87 x 50kg-size bags, which is only a fraction of the volume of indigenous plant species sold in South Africa. Even though the trade in alien plant species is low in comparison to the indigenous plant species traded, there are five alien species that are sold in volumes comparable to popular indigenous species sold. The large volumes of these species sold indicate that they are in high demand, specifically by *muthi* shops and Indian customers, as these species were not sold in any of the markets. In addition, most of the alien plant species including invasives were stocked in low volumes, but have been recorded in various studies, indicating the continuing demand for them.

CHAPTER 6: SOURCE OF ALIEN PLANT SPECIES RECORDED IN THIS STUDY

6.1 Introduction

The growth and development of trade, transport and travel, as well as activities such as agriculture, forestry and horticulture are causes of many plant introductions and invasions (Le Maitre *et al.*, 2004; Dehnen-Schmutz *et al.*, 2007a; Dehnen-Schmutz *et al.*, 2007b). The actions and activities of humans thus facilitate invasions (Le Maitre *et al.*, 2004). Le Maitre *et al.* (2004) discuss the driving factors affecting plant invasions, including: "*human population growth and migration*" and "*an expanding network of international trade and travel links*". With regards to the first factor, when demand outweighs supply for food or materials, people tend to migrate and transport with them propagules of their customary food and medicinal plant species, thus intentionally carrying with them potentially invasive species. The second factor refers to the manner in which trade routes, international links and the number of potential invasion pathways have dramatically increased during the last century (Le Maitre *et al.*, 2004; Dehnen-Schmutz *et al.*, 2007b). Plant species are inadvertently transported in ship ballast water, by tourists purchasing souvenirs, by seeds being moved in containers, transport vehicles, soil or contaminated seed lots (Le Maitre *et al.*, 2004; Dehnen-Schmutz *et al.*, 2007a).

Alien plant species in the South African traditional medicine trade are transported around the country and some are even regularly imported from India. By investigating the source and the destination of these plant species, the management of invasions can be monitored. This chapter investigates the source, harvesting localities and end points of the alien plant species sold for traditional medicine in Johannesburg, Durban and Pretoria.

6.2 Methods

The sources of the alien species recorded in this study were determined by asking the traders whether a particular species in question was harvested or bought and also what the source of the plant was, i.e. in which town or province the species was harvested. This source was enquired about even if the plant was purchased by the trader and not harvested themselves. *Muthi* shop traders were specifically asked if they sold any plant species that originated from India. In order to find out how they obtain any species from India, the trader was also asked

who their supplier was. Lastly shops traders were asked if they sold other alien plant species that were on the list of species to enquire about (Appendix 2).

Alien species recorded as being harvested and also imported from India were identified. These species harvested in South Africa and also imported from India were compared between similar outlets, i.e. Faraday and Warwick markets; Johannesburg, Durban and Pretoria *muthi* shops.

When analysing the results from the survey above, missing source data was completed by the following approach: when a particular species was reported to occur from either South Africa or India and another trader from the same type of outlet was not sure of the source of the same species, then the unspecified source was ignored and the known source (South Africa or India) for that particular instance was applied.

6.3 Results

6.3.1 **Type of retail outlet in relation to source of alien plants**

The alien plants sold in the *muthi* markets were predominantly harvested in South Africa (80%) (Figure 6.1), and a small percentage (17%) of species were from India. A very small percent (1.4%) of the alien plants sold were also harvested from Mozambique and Zimbabwe. Since this percent is so small, it was included in the percent of species being sourced from southern Africa. The opposite was noted for *muthi* shops, where a higher percentage of species were imported from India (43%) (Figure 6.1). There is a significant difference (t_{94}=-6.06; p <0.0000) in the imported number of alien species traded in shops compared to markets, but none for locally harvested alien species. Imported alien plant species in the markets were sold in pre-packaged transparent packets that usually hung on a string or on the side of traders' stall which were bought from *muthi* shops who imported them from India.

In both markets, three alien species, *G. glabra* L., *H. isora* L. and *W. somnifera* were obtained from two sources, i.e. harvested in South Africa and also imported from India (Table 6.1), but were predominantly sourced from India (Table 6.1). However, in all *muthi* shops *A. calamus*, *F. vulgare* and *W. somnifera* were the alien species that were both imported from India and harvested in South Africa (Table 6.1). *Foeniculum vulgare* sold in

all shops was predominantly harvested in South Africa, whereas *W. somnifera* was mainly imported from India (Table 6.1).

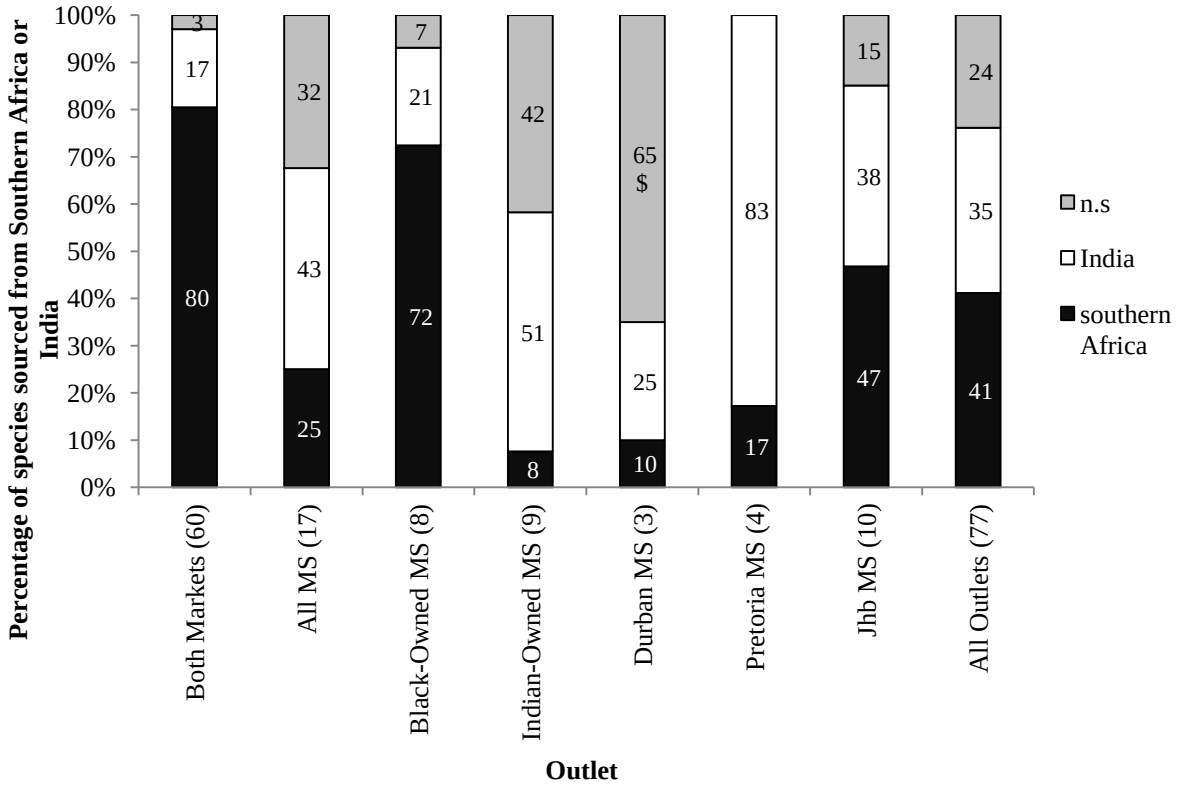


Figure 6.1. The percentage of alien plant species sourced from southern Africa* or India in relation to the outlets where they are sold. 'n.s' = source not specified. Sample size (number of traders, n) is in brackets. The alien plant species were sold in Faraday and Warwick traditional medicine markets and in Johannesburg, Durban and Pretoria *muthi* shops (MS). *Includes South Africa, Mozambique and Zimbabwe. $ Indicates that to most of the not specified sources of alien species sold at Durban MS, were imports from India.

The plant species recorded in this study are exotic to South Africa. However, *W. somnifera* is the only species listed in this study that occurs from South Africa to southern Europe and Asia (including India) (Van Wyk *et al.*, 1997; Van Wyk and Wink, 2004), and is included in this study because 50% of the traders that sold it indicated that it had been obtained (imported) from India and not from South Africa.

Seven of the species most frequently recorded in the markets and *muthi* shops are: *A. calamus, H. isora, G. glabra, W. somnifera, F. vulgare, Melaleuca leucadendron* and *H. gardnerianum* (Table 6.2). *Acorus calamus* and *H. gardnerianum* were predominantly harvested in KZN (71% and 73% respectively); *F. vulgare* and *M. leucadendron* were generally harvested in both KZN (33% and 25%) and Gauteng (17% and 25% respectively) (Table 6.2). *Glycyrrhiza glabra* was predominantly imported from India but also harvested in

KZN, Limpopo, Mozambique (Table 6.2). Eighty one percent of *Helicteres isora* sold in the markets and MS was imported from India, with 10% reportedly harvested in KZN (Table 6.2). *Withania somnifera* was reportedly sourced equally from South Africa and India (50%) (Table 6.2).

It should be noted though, that for instances where *H. isora* is reported to be harvested in KZN, the trader reporting this source most probably bought this species from a trader in KZN who had imported it from India but assumed it was harvested in South Africa.

The six invasive species sold in this study were all largely harvested in KZN. *Anredera cordifolia*, *O. ficus-indica* and *R. communis* were all harvested in both KZN and Gauteng. *Hedychium gardnerianum* was harvested in KZN and Eastern Cape. *Bryophyllum delagoense* was only harvested in Gauteng and the last invasive alien species, *C. camphora*, was only reported to be harvested in KZN (Table 6.2). The harvesting localities all match with the current distributions documented by AGIS (AGIS, 2013) (Table 6.3).

Table 6.1. Alien plant species sold at various outlets where some respondents indicated that plants are imported from India, while others noted they are harvested in South Africa. (Notation: Number of Records imported / Number of Records Harvested).

Botanical name	Outlets						Total per species
	Both markets	All MS	Jhb MS	Pretoria MS	Black-owned MS	Indian-owned MS	
Acorus calamus		2/2		1/1			3/3
Anacardium occidentale						1/1	1/1
Foeniculum vulgare		1/4		1/1		1/1	3/6
Glycyrrhiza glabra	6/1		2/3		1/3		9/7
Helicteres isora	11/1		2/1		2/1		15/3
Withania somnifera	3/1	4/2	1/2				8/5

Table 6.2. Source of the alien plants and the frequency with which they were reported to originate from South African provinces, surrounding countries or from India. Total number of traders interviewed was 77, including both traditional medicine market and *muthi* shop traders. Abbreviations for provinces and countries: EC=Eastern Cape; FS=Free State; GT=Gauteng; KZN=KwaZulu-Natal; LM: Limpopo; MP=Mpumalanga; MOZ: Mozambique; ZIM: Zimbabwe. n.s: source not specified. Unidentified taxa are listed by their vernacular names.

Species or vernacular name	KZN	GT	EC	LM	FS	MP	MOZ	ZIM	India	n.s	Total
Acorus calamus	22		1		1	1			1	5	31
Anacardium occidentale							1		1		2
Andrographis paniculata										1	1
Anredera cordifolia	5	2								1	8
Araucaria heterophylla	4										4
Areca catechu										2	2
avalkadle										1	1
Brassica sp.									2	1	3
Bryophyllum delagoense		1									1
Bryophyllum sp.	2	1								1	4
Cassia angustifolia									4	5	9
Cassia fistula	1								2		3
Cinnamomum camphora	4									3	7
Cinnamomum sp.									2	1	3
Coix lacryma-jobi	7		1							1	9
Commelina benghalensis				1							1
Coriandrum sativum		1								1	2
Curcuma longa									3	2	5
dumapansi									7	3	10
Eleutherine bulbosa	1									3	4
Foeniculum vulgare var.	4	2			1				1	4	12
girmalasing										2	2
Glycyrrhiza glabra	2			1			1		11	5	20
Hedychium gardnerianum	8		1							2	11
*Helicteres isora**	1								17	2	21
ibande								1			1
inderjow									1	1	2
Indian pearls									2	3	5
inhlanhla emhlophe	6										6
iphengula	2									1	3
kachka										1	1

Species or vernacular name	KZN	GT	EC	LM	FS	MP	MOZ	ZIM	India	n.s	Total
kamal kadi									2	3	5
kapoor kachi										1	1
Macadamia sp.	1										1
Melaleuca leucadendron	4	3		1						4	12
Mimosa pudica var.										1	1
Opuntia ficus-indica	7	1									8
Opuntia robusta	4	1							1		6
Pedilanthus tithymaloides	3					1	1				5
Platycarpha sp.										1	1
Quercus infectoria									2		2
Ricinus communis	4	1								1	6
Sansevieria cylindrica	3										3
Sansevieria fasciata	1										1
Senna sp.										1	1
Spilanthes mauritiana	5										5
Terminalia chebula									2	2	4
unukani oyikhambi	3		1							5	9
Withania somnifera	1		1	1					7	4	14
Total	106	13	5	4	2	2	3	1	68	75	279
% alien species from each province or country	**39**	**5**	**2**	**1**	**1**	**1**	**1**	**0.4**	**24**	**28**	

* This species was reportedly harvested in KZN, but was likely purchased from suppliers in KZN who were unaware that it was imported from India.

6.3.1 **Race of retail outlet owner in relation to source of plants**

Indian-owned *muthi* shops had a significantly higher proportion of species that were imported from India compared to Black-owned shops (51% and 21% respectively, Figure 6.1). Indian-owned shops obtained the following species from both India and South Africa: *A. occidentale* and *F. vulgare* (Table 6.1). *Withania somnifera* and *G. glabra* were the only species that were sourced from India more often than South Africa (Table 6.2). *Anacardium occidentale* and *F. vulgare* sold in Indian-owned shops were equally sourced from either India or South Africa (Table 6.1). Black-owned shops on the other hand, sold the following species from India and South Africa: *G. glabra* and *H. isora* (Table 6.1). *Helicteres isora* was the only species sold in Black-owned shops that was obtained more often from India than South Africa (KZN) (Table 6.1).

Table 6.3. Current distribution of the six invasive species sold in this study as documented by AGIS (2013). Abbreviations include: EC: Eastern Cape; FS: Free State; GT: Gauteng; KZN: KwaZulu-Natal; LM: Limpopop; MP: Mpumalanga; NW: North West; NC: Northern Cape and WC: Westen Cape.

	Provinces								
Species	EC	FS	GT	KZN	LM	MP	NW	NC	WC
Anredera cordifolia	✓	✓	✓	✓	✓	✓	✓		✓
Bryophyllum delagoense	✓	✓	✓	✓	✓	✓	✓		✓
Cinnamomum camphora	✓	✓	✓	✓	✓	✓			✓
Hedychium gardnerianum	✓	✓	✓	✓	✓	✓			✓
Opuntia ficus-indica	✓	✓	✓	✓	✓	✓	✓	✓	✓
Ricinus communis	✓	✓	✓	✓	✓	✓	✓	✓	✓

6.3.2 **Region of retail outlet in relation to source of plants**

Durban and Pretoria shops both sold more alien species that were imported from India than those that were harvested in South Africa. Even though Durban shops sold many alien species with unknown sources, many of the species were in fact imported by Khan Wholesalers from India, therefore it is estimated that 90% (25% reported from India and 65% not specified) were imported from India (Figure 6.1). Nonetheless, Johannesburg shops sold more species that were harvested in South Africa compared to Pretoria shops (Figure 6.1). A significant difference between the number of alien species harvested in South Africa was observed between Johannesburg and Pretoria shops (t_{94}=2.11; p > 0.037), with Johannesburg

selling the highest number of harvested alien plant species. Pretoria shops received *A. calamus* from India and from South Africa as well as *F. vulgare* (Table 6.1).

6.4 Discussion

6.4.1 **Type of retail outlet in relation to source of plants**

The majority (80%) of the alien plant species sold in the markets were harvested in South Africa, with 17% being imported from India (Figure 6.1). The 'South African' alien species (i.e. alien plant species that were harvested in South Africa) are naturalised in South Africa and are harvested by gathers (Williams *et al.*, 2001; Williams *et al.*, 2007a), and sold to the market traders (or, the traders harvest the plants they sell). The Indian imported alien species sold at the markets are purchased from Indian shop owners.

Traders in this study often cited harvesting areas like Manguzi or uMhlabuyalingana in KZN as sources of the naturalised aliens. However, due to time constraints, these harvesting localities were not compared with the documented distributions of the alien species in South Africa. However, on a provincial scale, the harvesting localities mentioned by the traders corresponded with the distributions documented by AGIS (2013).

It should be noted that traders and harvesters have a good understanding of the plant species used for traditional medicine – both in identifying plant species in the field and also understanding what is available in the field. This is because many traders and harvesters have been harvesting, buying and selling plants from wild populations for many years (Cunningham, 1991). However, in the case of imported species such as *H. isora,* traders were not always sure of the source of the alien plant species they sold. Therefore traders would either report the source as the area where the species was purchased or they would say that they were not sure. This indicates that the information given by the market and shop traders needs to be interpreted with caution.

KwaZulu-Natal was found to be the predominant source (39%) of the naturalised alien plant species in this study (Table 6.2). A similar result was observed for indigenous and alien plant species sold on the Witwatersrand in 1994 (Williams *et al.*, 2000). This shows that KZN is the province that supplies most alien and indigenous plant species to the *muthi* trade, which has also been reported by Williams (1992) and Mander (1998a).

The imported alien plant species used in the various outlets in this study are also used for medicine in India (Table 6.4) (Joshi *et al.*, 2005; Dev, 2012). Since these species are imported into South Africa from India, it may appear that these species actually grow in India. On the contrary, Narasimhan *et al.*(1999), Soundrapandi and Narasimhan (2006) and Attas (2003) report that several plant species (*G. glabra*, *Q. infectoria* and *W. somnifera*) are imported into Tamil Nadu (India) from other countries and then exported to other countries, such a South Africa. (Table 6.5).

Table 6.4. Botanical names of plant species that are used both in South Africa and India for traditional medicine. [adapted from (Joshi *et al.*, 2005; Dev, 2012)].

Botanical name	
1. *Acorus calamus*	9. *Glycyrrhiza glabra*
2.*Anacardium occidentale*	10. *Helicteres isora*
3. *Areca catechu*	11. *Mimosa pudica*
4. *Cassia angustifolia*	12. *Quercus infectoria*
5. *Coix lacryma-jobi*	13. *Ricinus communis*
6. *Coriandrum sativum*	14. *Terminalia chebula*
7. *Curcuma longa*	15. *Withania somnifera*
8. *Foeniculum vulgare*	

Table 6.5. The origin of plant species common to South African and Indian traditional medicine which are sold in Chennai and Viruthunagar markets in Tamil Nadu, India. Data adapted from: (Narasimhan *et al.*, 1999; Attas, 2003; Soundrapandi and Narasimhan, 2006).

Species	Origin
Acorus calamus	Cultivated in India
Curcuma longa	Cultivated in India
Glycyrrhiza glabra	Afghanistan and Iran
Helicteres isora	West Bengal and cultivated in India
Quercus infectoria	Nepal
Terminalia chebula	Harvested in India
Withania somnifera	Afghanistan and Iran and cultivated in India

Tamil Nadu has a selection of markets that trade in medicinal plants, with Chennai and Viruthunagar markets being examples of regional and intermediate size markets (Attas, 2003). Chennai is in the north–eastern part of Tamil Nadu and Viruthunagar is in southern India (Attas, 2003).

With Chennai market being a regional market, it serves as a channel for plant species that are harvested from all over southern India and are then supplied to other markets. Viruthunagar market on the other hand, has an "*intermediate position in the downward flow of plant materials for local use and upward flow of plant material to central and regional markets*" (Soundrapandi and Narasimhan, 2006). Some of the species sold in the two markets are grown in India, some cultivated and others are imported from other countries (Table 6.5) (Narasimhan *et al.*, 1999; Soundrapandi and Narasimhan, 2006). Therefore it is evident that some of the alien species sold in this study that are imported from India, are not necessarily from India.

6.4.2 **Race of retail outlet owner in relation to source of plants**

The Black-owned *muthi* shops were similar to the markets in that they sold a higher percentage of naturalised alien species harvested within South Africa (72%) than species imported from India (Figure 6.1). The naturalised alien species sold in the Black-owned shops were bought from the Faraday market, and were predominantly harvested in KZN. On the other hand, the imported Indian species stocked at Black-owned shops were purchased from Indian-owned shops. This study is not the first to record shops possessing stock from India, e.g. Williams *et al.* (1992, 1997, 2000, 2001) and Stafford *et al.* (2008), including species such as *C. camphora, H. isora, G. glabra, W. somnifera* and *dumapansi*.

Indian-owned shops primarily sell alien species that were imported from India (51%), (Figure 6.1) which are obtained via Khan Wholesalers. As is common, the naturalised alien species that are sold in Indian-owned shops were purchased from the markets (Williams, 2003; Williams *et al.*, 2005a; Williams, 2007). Since a large proportion of the South African Indian traders are Tamil-speaking Hindus (Williams, 2007) with cultural and familial links to India and the province of Tamil Nadu, it is unsurprising that trade networks between India and South Africa exist to supply a demand for plants only obtainable from Asia.

It is evident that certain customs persist following immigration. For example, Witchcraft or "Santería" continues to form a vital part of the customary healing practices among Latino immigrants in New York (Balick *et al.*, 2000). Furthermore, recent research noted that traditional medicine is not replaced by conventional health care (Balick *et al.*, 2000). An example of this was observed in Surinamers of Chinese, Javanese and East Indian descent

migrating to the Netherlands during 1972–1996. Even though they migrated and had access to improved modern health care, there was continued demand for their traditional medicine despite difficulties in obtaining/importing these (Van Andel and Van ‘t Klooster, 2007). Therefore it is assumed that the South African Indian population retained some cultural and trade links to India through their traditional medicine.

6.4.3 **Region of retail outlet in relation to source of plants**

Johannesburg *muthi* shops sold more species that were harvested in South Africa than those imported from India compared to Durban shops. This is because most of the Johannesburg shops had Black owners (10 out of a total of 17) and the same explanation applies as in the Inventory Chapter (Chapter 3).

6.5 Conclusion

Traditional medicine markets (Faraday and Warwick) and Black-owned *muthi* shops sell the largest number of naturalised alien plant species harvested within South Africa. This is in comparison to other shops (primarily Indian-owned and in Durban) that sell more plant species imported from India. Indian-owned businesses sell imported alien plant species because there is a demand for it created initially by early Indian immigrants to South Africa which has continued today in the localised Indian culture and because Indian traditional medicine practices has been incorporated into Zulu medicine over the last 150 years.

The harvesting localities of the invasive alien species reported in this study by the market and shops traders broadly corresponded with the documented provincial distributions of the species. Since traders and harvesters have an extensive knowledge regarding species sold as herbal medicine, they can provide further specifics into localities and the size of the alien plant populations sold.

KwaZulu-Natal was the dominant source of the naturalised alien plant species sold in this study. On the other hand, India was found to be a origin of Indian plant species sold. Not only is it the country where some plant species used in South Africa and Indian are grown, but it also serves as a trade hub between South Africa and other countries.

CHAPTER 7: CONTINENTAL ORIGINS OF ALIEN PLANT SPECIES RECORDED IN THIS STUDY

7.1 Introduction

Plant species have been transported across the world, from one country to another, over millennia for a variety of reasons (Catford *et al.*, 2009; Hulme, 2009), ranging from the introduction of ornamentals, food, fibre, livestock, medicinal herbs to accidental inclusion with crops (Kornaś, 1990; Pyšek, 1998; 2000; Le Maitre *et al.*, 2004). Plant species are either introduced intentionally or unintentionally (Pimentel *et al.*, 2000) and many introductions have resulted in plant species becoming invasive in their new habitats (Hulme, 2009). Introduced plant species do not immediately become invasive once introduced into a new region however, as they go through a lag phase (Hobbs and Humphries, 2002). Thereafter a species may go through a process of colonization, naturalization, spread and impact (Catford *et al.*, 2009). Many species generally become invasive at the stages of 'spread' and 'impact' (Catford *et al.*, 2009).

Reasonable estimates of the consequences of alien species introductions can be made with the following information: the plant species traded, origin and destination as well as the "suitability for the receiving environment" (Hulme, 2009). However, all this information would only be available in an ideal world (Hulme, 2009). Nonetheless this study looks at the continental origin and destination of alien plant species traded for traditional medicine in South Africa.

Thousands of plant species have been introduced into South Africa since the 1600's and some have since become problematic. These problematic species have been described by Henderson (2001a). From a total of 238 invasive plant species present in South Africa in 2001, 50% originated from South, Central and Tropical America, 25% from Asia, Europe and the Mediterranean while 13% came from Australia (Moran *et al.*, 2011). The continental origins of alien plant species in the herbal medicine trade recorded in this study are investigated in this chapter.

7.2 Methods

7.2.1 **Continental origins of species in the this study and in the literature review**

The origins of most alien species recorded in this study and from the literature review (Appendix 5) were obtained from Glen (2002), and other origins were acquired from: Macself (1945); Bailey (1947); De Candolle (1967); Hedrick (1972); Morley (1974); Everett (1980); Dakshini and Prithipalsingh (1984); Liu *et al.* (2006) and Klein (2011).

Species in this inventory which were only identified to genus were not assigned origins. Similarly, some species were identified to species but had unknown origins and these species were removed from the analysis. Each country or area of origin for each known species were allocated to one of the seven continents for analysis. Where species had origins that spanned more than one continent, these contributed to each continent in equal weightings.

7.2.2 **Comparison of continental origins between this study and the literature review**

The continental origins of the alien plant species were counted for both this study and the literature review and the proportions of alien plant species originating from each continent were calculated. These proportions were tested for significant differences within this study and within the literature review. In addition, this study was compared to the literature review to establish whether the proportion of species that originated from each continent were statistically different. Pearson's Chi-squared test was used to compare the number of species originating from each continent within each study and between this study and the literature review.

7.3 Results

Alien plant species recorded in both this study of *muthi* shops and markets and the literature review originated mostly from Asia (16% and 22% respectively) (Figure 7.1 and Figure 7.2). A significant difference was found amongst the proportions of origins in the literature review, indicating that at least one of the continents had a statistically significant different proportion of alien species. In the literature review, most alien species originated from Asia although alien invasives were in equal proportions from Asia, South America & North America. The least number (16) of alien plant species originated from Australia, but half of these were invasives (Figure 7.2). The proportions of continental origins were similar between this study and the literature review with no significant difference found (Table 7.1).

With 12 plants being unidentified in this study, the highest percentage (33%) of plants had unknown origins in this analysis (Figure 7.1). These 12 unidentified plants and those that were imported from India, but not necessarily harvested in India, were counted and displayed in Figure 7.1, but were excluded from further analysis.

In this study, the following continents ranked next for having the most alien species used for *muthi* in South Africa: Africa, North America, Australia and South America (Figure 7.1). North and South America as well as Europe were also amongst the continents that had high proportions of alien plant species originating from them in the literature review (Figure 7.2).

Table 7.1. Comparison of the proportions of continental origins of alien plant species in this study and the literature review.

Study	# alien species (n)	Within study	Compared between studies
This study	49	n.s.	-
Literature review	320	χ^2=117.38, df=5, $p < 0.005$	n.s.

n.s.=not significant

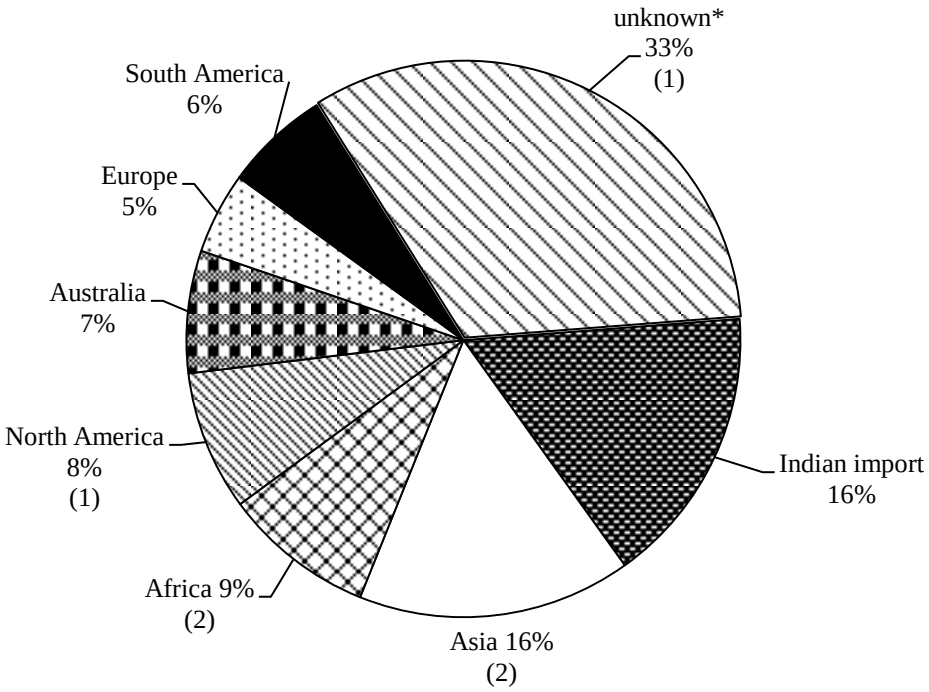


Figure 7.1. Continental origins of alien plant species recorded in this study that are used for traditional medicine. (S=49). The number of species with invasive status according to AGIS (2013) are indicated in brackets. *Unknown identity and thus unknown origin. 'Indian import' referred to species that were exported out of India into South Africa but did not necessarily originate from India.

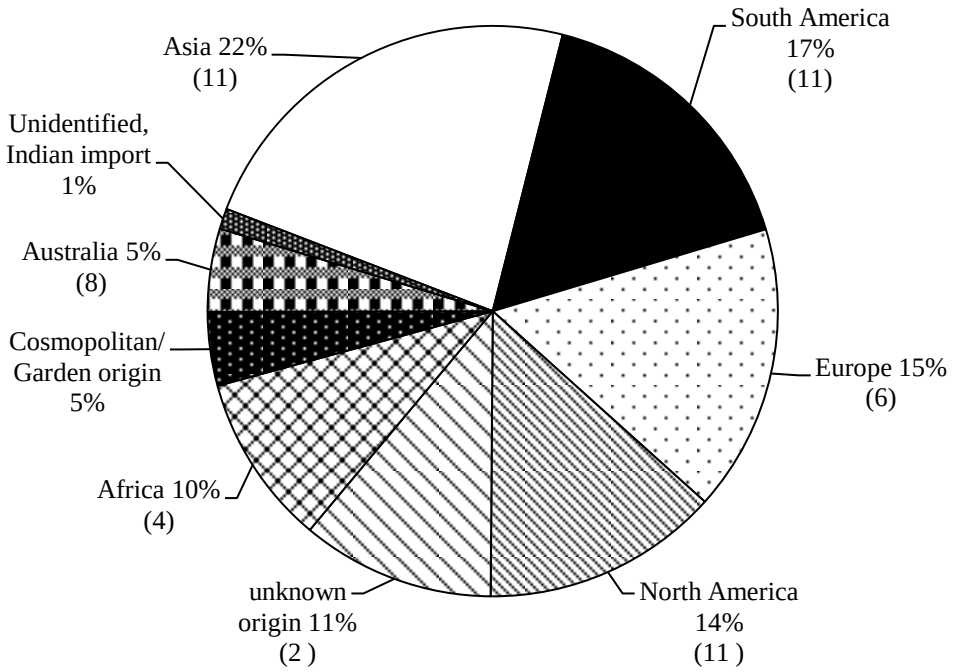


Figure 7.2. Continental origins of alien plant species recorded in the literature review that are used for traditional medicine (S=320). Fifty three species have invasive status according to AGIS (2013) and are indicated in brackets as number of species.

7.4 Discussion

The continental origins of alien plant species recorded as being used/sold for traditional medicine in this study (the survey and the literature review) were compared with three other studies of species used/sold for medicine in South Africa, namely: Williams *et al.* (2001) (alien species sold on the Witwatersrand); Hutchings (1989) (alien species used by Zulu, Xhosa and Sotho in the Eastern Cape); and, Dold and Cocks (2000) (alien species used in the Eastern Cape). In addition, these data were compared with a study by Klein (2011) that looked at biocontrol agents released against some of South Africa's worst invasive weeds (73).

Table 7.2. Significance of the proportions of alien plant species in each study that originate from various continents. Each study was also compared to this study regarding the proportions of alien plant species that originate from various continents. The continents were: Africa, Asia, Australia, Europe, North America and South America. In Klein (2011) some alien plant species came from cosmopolitan/garden origins, which was counted as a seventh 'continent'.

Study	# alien species (S)	Within study	Compared to this study
This study	49	n.s.	-
Hutchings (1989)	26	n.s.	n.s.
Williams *et al.* (2001)	19	n.s.	n.s.
Dold and Cocks (2000)	21	n.s.	n.s.
Klein (2011)	73	χ^2=55.29, df=6, $p < 0.005$	χ^2=72.32, df=6, $p < 0.005$

Only the study by Klein showed that at least one of the continents of origin of alien species differed significantly from the others. All other studies showed no continent being different from another (Table 7.2). This is reasonable because the other studies were on traditional medicine while Klein looked broadly at all invasive alien plant species present in South Africa.

In addition, the proportions of plant species originating from the different continents in Klein's study differed significantly from this study. This shows that the comparison of alien plant species' continental origins in this study is not similar to that of the invasive alien plant species in South Africa in general.

While India was the most prominent continent of origin for alien species traded in South Africa, North and South America and Australia were the most common origins making up 85% of South Africa's 73 most invasive species in general (Klein, 2011). Although only two

invasive species originating from India were reported in this study, the remaining six could potentially become invasive if introduced into habitats with similar environmental conditions. This phenomenon is explained by the homo-climatic hypothesis (Pyšek, 1998; Lee and Gelembuik, 2008).

Low percentages of alien plant species in this study (12%) and the literature review (16%) are regarded as invasive according to AGIS (2013). However, more alien plant species may become invasive in the future, due to the species being in a possible lag phase. A lag phase is the delay between the start of invasion and the period of exponential increase (Richardson and Pyšek, 2006). Lag phases can often take several decades or longer and range expansion of many introduced species often follows a logistic pattern with slow initial spread (Ewel *et al.*, 1999).

Multiple introductions of alien plant species can give rise to genetically diverse populations and the successful establishment and invasiveness of non-native species (Sakai *et al.*, 2001). It was observed that many of the alien plant species used for traditional medicine in South Africa are continuously imported from India and harvested in KZN and then transported around the country, constituting multiple introductions. Sakai *et al.* (2001) explains that when genetically diverse populations form as a result of multiple introductions, these populations can be even more diverse than any of the individual populations since they are less structured than in their native ranges. A species that has various colonizing populations is expected to be genetically divergent with different levels of genetic variation and as a result have different capacities to promote invasiveness. Traits that promote invasiveness may evolve in some populations but not others (Sakai *et al.*, 2001).

Pyšek (2004b) explains that one of the most promising predictors of a species becoming invasive is the size of its native geographical range. The wider the native range, the wider the potential range for establishment and eventual invasion. The sizes of native ranges, habitats and other invasive traits of the alien plant species in this study were beyond the scope of this study, but could be explained in future studies.

The larger the distribution of a species, the more likely it is that more of that species will be harvested (Williams *et al.*, 2000). Ethnobotanical studies on southern African floral families

have shown that there is a positive correlation between the plant families sold commercially and the size of their distribution in the wild. If through time there are more alien plant species available in the *muthi* markets and shops, this could indicate that there are more alien plant species in the wild in South Africa. Therefore this could be a way to monitor the spread of alien plant species in South Africa.

7.5 Conclusion

It can be concluded that the importation of plant species from Asia for traditional medicine has been significantly greater compared to imports from other continents into South Africa. Although a large majority of South Africa's invasive plant species come from North and South America and Australia for a variety of purposes these are not prominent in the medicinal plant trade. In addition, even though only 12% and 16% of alien plant species are invasive in this study and derived from the literature review, it is likely that many more alien plant species will become invasive as many species undergo multiple introductions and may already be in a lag phase.

CHAPTER 8: RICHNESS AND DIVERSITY OF ALIEN PLANT SPECIES IN THE SOUTH AFRICAN *MUTHI* TRADE

8.1 Introduction

Species richness, measured as the number of species observed, is the most basic component of species diversity and its estimation is one of the most general measures used in ecological research (Chiarucci *et al.*, 2003; Magurran, 2004). Ethno-ecological surveys of species richness usually face the challenge of establishing when an inventory is complete, as well as determining how many more species might be recorded if further sampling took place (Williams *et al.*, 2007b). In order to address this challenge, species richness estimators were used to estimate the number of alien plant species which could have been recorded if further sampling of *muthi* market and shop traders took place.

In order to assess whether a sufficient number of traders in each outlet were interviewed, species accumulation curves were created. Species accumulation curves demonstrate the rate at which new species are found for each new sampling occasion (Magurran, 2004). In addition, the similarity of alien plant species' identity between different outlets was recorded. Furthermore, the alien plant species that were unique to each type of retail outlet, or unique between the regions of the retail outlets, or unique to the race of the retail outlet owner were identified. Finally, in order to establish whether all of the sold alien plant species were occurring equally within markets and shops, the frequency of occurrence was calculated. This was calculated to determine if all of the alien plant species have an equal chance of establishing and possibly spreading through their use in the *muthi* trade.

8.1.1 **Sampling sufficiency**

Total enumeration of the number of species in an entire study area is often not achievable, due to harvesting localities being extensive and continuously expanding (Williams *et al.*, 2007b). The sampling efforts of ethnobotanical studies can be evaluated by plotting species accumulation curves. These curves demonstrate the rate at which new species are found by plotting the relationship between the cumulative number of observed species versus sampling effort (Begossi, 1996; Magurran, 2004; Williams, 2007; Williams *et al.*, 2007b). Adequate sampling effort is considered to have been achieved once the species accumulation curve reaches an asymptote (Soberon and Llorente, 1993; Toti *et al.*, 2000). Sampling effort can either be plotted as the number of samples or as the number of individuals (number of records

of a particular species). A statistical expectation of how many species are expected to be recorded, known as a rarefaction curve, is often also drawn (Magurran, 1988; Williams *et al.*, 2000; Williams, 2007). Both species accumulation and rarefaction curves were produced from the data in this study.

8.1.2 **Species richness and diversity**

Species richness, diversity and species similarity were calculated for each outlet in the study using *EstimateS*. Species richness refers to the observed number of species in a specified area, denoted by either is 'S' or 'N0'. Species diversity incorporates both species richness and evenness, which refers to how uniformly abundant species are in a sample (Magurran, 1988). This evenness may indicate if the alien plant species in the study are all present in the markets or shops in equally quantities.

Diversity can only be calculated using the number of traders interviewed, symbolized by 'n' as well as the number of individuals, denoted by 'N', which refers to each instance an alien species was recorded (Williams *et al.*, 2005a; Whiting *et al.*, 2011). An 'index' of diversity, also known as index of heterogeneity, consists of both species richness and evenness and combines them into a single value and is based on the proportional abundance of species in a sample (Whiting *et al.*, 2011).

The Shannon diversity index (*H*') calculates the average degree of 'uncertainty' associated with accurately predicting the identity of the next species selected at random (Pielou, 1975; Krebs, 1999). Uncertainty is said to be positively correlated to diversity, for as diversity increases, the degree of uncertainty in correctly predicting the identity of the subsequent species chosen at random also increases (Krebs, 1999; Whiting *et al.*, 2011). Shannon *H*' is sensitive to sample size (Williams *et al.*, 2005a).

Fisher's α is a value which signifies the number of species expected to be represented by one individual of that species (Williams *et al.*, 2005a). This diversity index is influenced by sample size, species richness and the number of species of intermediate occurrence (Whiting *et al.*, 2011). Fisher's α therefore predicts the number of species that will occur once, which is similar to another index known as singletons. The only difference between Fisher's α and singletons is that singletons refer to the species that were only found once in the sample (Chiarucci *et al.*, 2003; Whiting *et al.*, 2011). Fisher's α and singletons are worth calculating

and comparing due to the fact that in the process of calculating species diversity, the more species there are that only occur once in a sample, the greater the likelihood of finding more species that only appear once, therefore increasing the expected species diversity (Williams *et al.*, 2005a).

Evenness or equitability indices incorporate both the number of species and their relative abundances (Magurran, 1988; Krebs, 1999). Evenness values range from 0-1, with values close to 0 representing low evenness and certain species showing high dominance within the sample. Therefore high evenness values (close to 1), indicate that species are evenly distributed within the sample resulting in the dominance of species being more or less equal to each other and on the whole, the dominance being low (Begossi, 1996; Krebs, 1999; Whiting *et al.*, 2011). The evenness values were calculated using EstimateS. Hill's diversity numbers represent the number of abundant (N1), very abundant (N2) and most abundant (N∞) species in a sample and are mathematically linked to Shannon, Simpson and Berger-Parker indices. Hill's diversity numbers were not analysed but were used to calculate which species are of "rare", intermediate and of common abundance. Sørenson's similarity index was calculated using EstimateS to compute the degree of species similarity between the sites. This index provides an understanding of the percentage of species that are common between various markets and MS.

8.1.1 **Estimators of species richness**

Species richness estimators predict the total sample species richness using the frequency of "rare" species calculated in a sample (Williams *et al.*, 2007b). Incidence-based species richness estimators were calculated using the free software *EstimateS* (Version 7.5) (Colwell, 2005). Incidence-based data refers to species being recorded as present or absent in a market or shop.

8.2 Methods

8.2.1 **Sampling sufficiency for the number of studies reviewed for the literature review and for the number of traders interviewed for this study**

Accumulation and rarefaction curves were produced using the program *EstimateS* for both the reviewed studies and the species recorded in this study. A species accumulation curve,

plotting the number of studies reviewed versus the cumulative number of species recorded per reviewed study was plotted. The curves were created in order to determine a) whether an ample number of studies were reviewed to adequately represent the number and diversity of alien plant species that are used for traditional medicine in South Africa, and b) whether an adequate number of traders had been sampled within each type of retail outlet in this study. A species accumulation curve, plotting the number of studies versus the cumulative number of species recorded per reviewed study was plotted. This curve was created in order to determine whether an ample number of studies were reviewed to adequately represent the number and diversity of alien plant species that are used for *muthi* in South Africa.

8.2.2 Observed species richness and diversity of alien plant species sold in South African *muthi* trade

The richness and diversity of alien plant species sold in the Faraday and Warwick markets, as well as the shops in Durban, Johannesburg and Pretoria, were calculated and compared. The number of alien plant species sold by each trader in the various outlets was recorded and thereafter the diversity was calculated. The diversity measures that were calculated include Shannon diversity index, Fisher's α, Evenness E1 and Hill's number N1 and N2. In addition to species richness and diversity being calculated for the sites in this study, these values were compared with a Faraday survey conducted in 2001 and the Witwatersrand *muthi* shop survey conducted in 1994 which examined the diversity of plant species used for TM in the Witwatersrand (V.L. Williams unpublished data).

8.2.3 Estimating species richness

In order to estimate the number of alien plant species that could have been recorded if further sampling took place, the following species richness estimators were used: ICE, Chao 2, first-order and second-order Jackknife (later referred to as Jack 1 and Jack 2), Bootstrap and MMMeans. These estimators are the best for estimating species richness for incidence-based (i.e. presence/absence) data.

The various estimators predict the species richness of a sample and all usually give different estimates, therefore the best estimator(s) needs to be determined. Ways to determine the best estimator include: a) comparing the estimator's result with that of the observed species

richness recorded for that particular sample-the estimator should give a result equal to or greater than the observed species richness; b) observing whether the estimator reaches an asymptote; and c) choosing the estimator that best predicts the observed species richness of the total sample based on the data of subsamples (Toti *et al.*, 2000; Williams *et al.*, 2007a). The estimators that gave the best, or upper- and lower-bound, estimation of alien species richness for each outlet were presented.

8.2.4 Similarity of alien plant species sold in traditional medicine markets and *muthi* shop outlets

The number and percentage of similar species between various outlets was calculated using Sørenson's similarity index in *EstimateS*. A matrix showing the number and percentage of the similarity between various outlets was then created. Similarly, a table indicating which alien species were similar between the outlets was also created. In addition, a table indicating which outlets had the greatest similarity and the least similarity with other outlets was created.

8.2.5 Frequency of species occurrence

In calculating the number and the percentage of species that were of common, intermediate and "rare" occurrence in the *muthi* markets and shops, Hill's diversity numbers were calculated and transformed from values obtained in *EstimateS*. The term "rare" refers to a species that is in low abundance in a sample and does not mean that the species is endangered (Williams *et al.*, 2005a.). To prevent confusion and for the purposes of this study, the term "rare" was modified to "uncommon" occurrence. Hill's diversity numbers were transformed from the EstimateS values in the following way: The number of common species as approx. $N\infty$, the number of species of intermediate abundance as $\approx (N1-N\infty)$ and the number of uncommon species as $\approx (N0-N1)$ (Williams *et al.*, 2005a). Numbers and percentages of species occurrence are presented. The formula and notations for this are further developed in the results Table 8.1.

8.3 Results

8.3.1 **Sampling sufficiency for the number of studies reviewed for the literature review**

The studies used in the literature review combined with this study, provide a good representation of the alien plant species used for traditional medicine in South Africa (Figure 8.1). Even though the curve did not reach an asymptote, the rate of accumulation of new species when the last study was reviewed, was five new species per new published study consulted (which was about three times less than at the initial stages of the investigation).

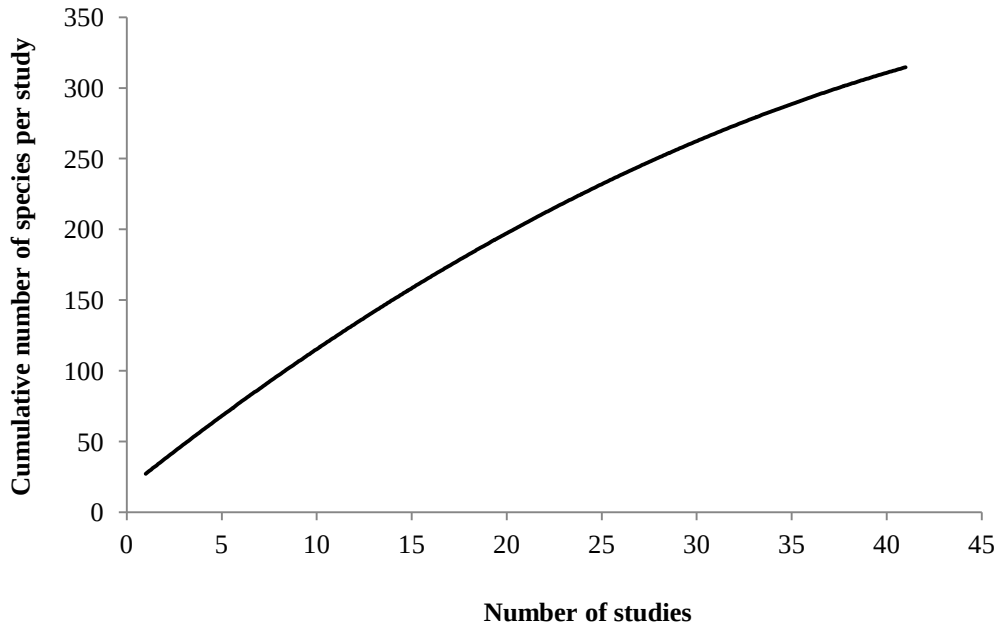


Figure 8.1. Species accumulation curve for the number of alien plant species used for traditional medicine in South Africa recorded per study reviewed. Forty studies were reviewed and dated from 1895 to 2011.

8.3.2 **Sampling sufficiency of the number of traders interviewed for this study**

Type of retail outlet

The Warwick market species accumulation curve approached an asymptote of 1 new alien species for every 6 traders interviewed, while Faraday market accumulated 1 new alien species for every 4 traders interviewed (Figure 8.2a). Nonetheless, the curve of 'both markets' approached an asymptote (Figure 8.2a) and the number of traders interviewed can be considered adequate. The species accumulation curves for *muthi* shops (MS) in Durban,

Pretoria and Johannesburg strongly indicate that more alien plant species would be revealed if more surveying of these outlets took place. However, all the MS combined resulted in only one new species being recorded per trader when the last trader was interviewed and the curve starting to reach an asymptote (Figure 8.2a).

Race of retail outlet owner

The species accumulation curves of Indian and Black-owned MS started flattening out. This indicates that few new alien plant species were recorded by the time the ninth MS owner was interviewed, compared to ten new species per trader that were recorded after the first Indian-owned MS trader was interviewed (Figure 8.2b). On the other hand, the species accumulation curve of Black-owned MS indicates that only one new species was recorded after the last trader was interviewed compared to 4 new species that were recorded when the first trader was interviewed (Figure 8.2b).

Region of retail outlet

In Johannesburg and Durban outlets, it was observed that only one new alien species per additional trader was added after the last trader was interviewed, compared to four new species being recorded when the first trader was interviewed. The species accumulation curves for both cities started flattening out after the last trader was interviewed, indicating that the sampling effort for both cities was sufficient and that it was unlikely that new alien species would be found in the markets with further sampling (Figure 8.2b). From all the market and MS traders in all of the outlets, only one new alien plant species was recorded during the final interview. This small increase in species number on the species accumulation curve caused the curve to approach an asymptote (Figure 8.2b).

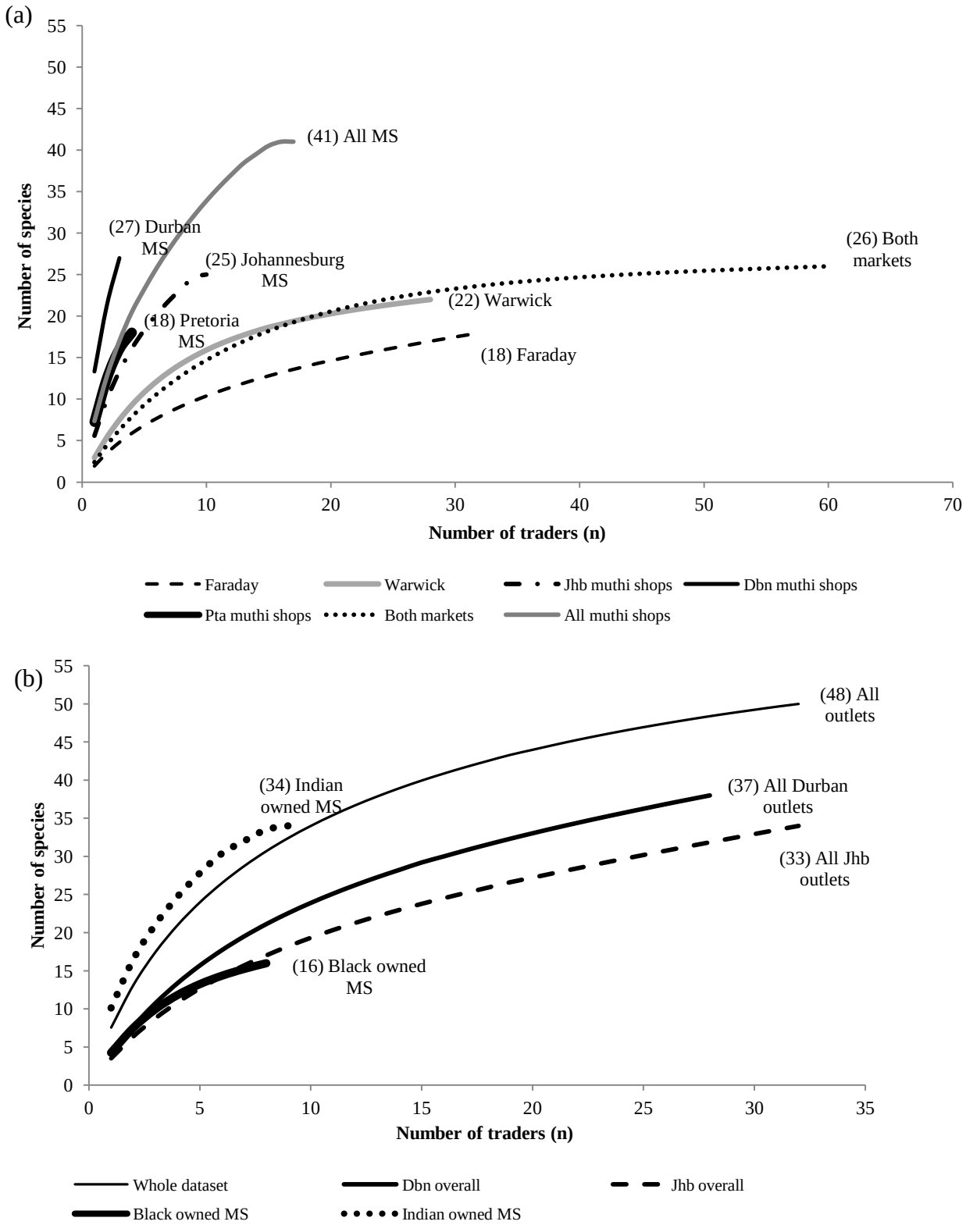


Figure 8.2. Species accumulation curves for the number of alien plant species recorded per trader interviewed at various outlets in this study (a) Faraday and Warwick markets; both markets combined, and *muthi* shops (MS) in Johannesburg, Durban and Pretoria, and all the MS combined (All shops). (b) Indian and Black-owned MS, and all Durban outlets, which includes the Warwick market and Durban MS, all Johannesburg outlets, which includes the Faraday market and Johannesburg MS. All outlets, refers to the markets as well as the three types of MS.

8.3.3 **Observed species richness and diversity of alien plant species sold in South African *muthi* trade**

Type of retail outlet

The alien plant species richness and diversity in the Warwick market (S=22 species; H'=2.89) was slightly higher than the richness and diversity of alien species sold in Faraday (S=18; H'=2.48), even though fewer traders were interviewed at Warwick (Table 8.1). The combined result for both markets indicated that a mean of 20.8 ± 5.7 alien plant species were sold per trader (Table 8.1). The diversity of both markets was lower compared to that of the MS, where a total of 41 alien species were recorded (*H'*=3.00 and *H'*=3.43 respectively) (Table 8.1).

Durban MS had a higher diversity of species compared to Johannesburg MS (*H'*=3.22; and *H'*=3.07 respectively) followed by the Pretoria MS (Table 8.1). Furthermore, the mean number of alien species sold per shop trader was 30% greater than the number of alien species sold per market trader (29.8±10.7; 20.8±5.7 respectively) (Table 8.1).

Race of retail outlet owner

Comparing the mean species richness sold by Indian and Black-owned MS, the former outlets sold double the number of alien species compared to the latter (25.95 ± 8.7; 11.55 ± 4.08 respectively) (t_{15}=-4.34; p=0.0006) (Table 8.1). In addition, the diversity of species sold by Indian-owned MS were higher compared to the diversity of Black-owned MS (*H'*=3.33; *H'*=2.65 respectively) (Table 8.1).

Region of retail outlet

All Durban outlets (Warwick market and Durban MS) had a slightly higher species diversity compared to all Johannesburg outlets (*H'* = 3.33; *H'* = 3.12 respectively, Table 8.1). A small difference was observed in the mean number of alien plant species sold in all Johannesburg and Durban outlets (23.1 ± 8.4; 26.4 ± 9.5 respectively) (Table 8.1).

Table 8.1. Comparison of diversity measures between traditional medicine (TM) market and *muthi* shop (MS) outlets in Johannesburg (JHB), Durban (DBN) and in Pretoria.

Index/Measure	Faraday market	Warwick market	Both markets	JHB MS	DBN MS	Pretoria MS	Indian-owned MS	Black owned MS	All *muthi* shops (MS)	All JHB outlets	All DBN outlets	All outlets
# interviewed traders (n)	32	28	60	10	3	4	9	8	17	32	28	77
# plants recorded (N)	62	82	134	59	40	30	96	34	125	113	123	259
Species richness observed (S)	18	22	26	26	28	18	34	16	41	33	37	49
Mean S per trader ± SD	12.4±44	16.6±5	20.8±5.7	17.9±6.7	20.9±7.4	13.4±4.7	25.9±8.7	11.6±4.1	29.8±10.7	23.1±8.4	26.4±9.5	37.7±11.4
Shannon (*H'*)	2.48	2.89	3.00	3.07	3.22	2.83	3.33	2.65	3.43	3.12	3.33	3.54
Fisher's α	8.5	9.9	9.6	17.8	41.7	19.0	20.9	11.8	23.2	16.5	18.8	19.1
Evenness E1 (Shannon *J'*)	0.86	0.93	0.93	0.94	0.97	0.98	0.93	0.96	0.91	0.88	0.92	0.90
Hill's N1	11.9	17.9	20.7	21.5	25.0	16.9	27.9	14.2	30.9	22.7	27.9	34.5
Hill's N2	10.0	19.2	19.3	26.3	48.8	33.5	29.4	20.0	28.8	19.3	26.5	29.5
Hill's N∞	4.4	8.2	5.2	9.8	13.3	10.0	12.0	8.5	11.4	6.7	10.3	7.8
N_{max}	14	10	26	6	3	3	8	4	11	17	12	31
Singletons	8	5	4	12	20	7	14	6	16	17	15	12

Where,

H'_{max} = ln S

J' = H'/H'_{max}

N1 = $e^{H'}$

N∞ = N/N_{max}

N_{max} = the number of the most frequent species in the sample

And, Hill's N0 = S

The evenness values for Warwick versus Faraday, Durban MS compared to Johannesburg MS, Black-owned MS versus Indian-owned MS, and all Durban outlets in relation to all Johannesburg outlets, all indicate that Durban had a slightly higher evenness, and hence lower dominance, of alien plant species compared to Johannesburg (Table 8.1). The higher evenness in Durban means that the alien species sold are almost equally present amongst the MS and market traders, whereas in Johannesburg MS and market, there are some alien species that are more prevalent than other species.

The lower and upper bound estimators of alien plant species for Johannesburg MS (31; 46), Durban MS (34; 47) and Pretoria MS (21; 25) were again Bootstrap and Jack 2 (Table 8.2, Appendix 6d, e and f). Jack 1 predicted the best estimations of alien plant species for the Johannesburg MS (38), Durban MS (41) and Pretoria MS (24), as well as all of the MS (All MS) (59). Jack 1 was the best estimator because the curve generally approached an asymptote and was between the lower and upper estimators (Table 8.2, Appendix 6d, e and f). The graph of cumulative number of individuals versus the cumulative number of alien plant species for 'All MS' indicate the same as the individual MS, that Jack 1 provided the best estimation of alien plant species, whereas Bootstrap and Jack 2 provided good lower and upper bound estimations of alien plant species for all the MS together (Table 8.2, Appendix 6g).

Race of retail outlet owner

Indian and Black-owned MS were estimated by Jack 1 to have 14 and 5 additional alien species respectively (Table 8.2) – this was above the 34 and 16 species already recorded, totalling 48 and 21 alien species in Indian and Black-owned MS respectively (Table 8.2, Appendix 6h & i). Jack 1 was the best estimator for Indian and Black-owned MS as it approached an asymptote and provided a good estimation of alien species between the lower and upper bound estimators Bootstrap and Jack 2 (Table 8.2, Appendix 6h and i).

Table 8.2. Difference between observed species richness and incidence-based (present or absent) species richness estimators for markets and *muthi* shops (MS) outlets in Johannesburg (JHB), Durban and Pretoria. Values in **bold** are the best estimators of alien plant species for a particular outlet and the other values are the lower and upper bound estimators.

Outlet	# traders interviewed (n)	Observed species richness (S)	Best estimators of species richness			
			Bootstrap	Jack 1	Jack 2	MMMeans
Markets						
Faraday	32	18	21	**26**	31	
Warwick	28	22	24	**27**	29	
Both markets	60	26	28	**29**	31	
Muthi shop locality						
JHB MS	10	25	31	**38**	46	
Durban MS	3	27	34	**41**	47	
Pretoria MS	4	18	21	**24**	25	
All MS	17	41	51	**59**	63	60
Muthi shop ownership						
Indian-owned MS	9	34	42	**48**	52	52
Black-owned MS	8	16	19	**21**	23	
Market and Ms locality						
All JHB outlets	32	33	41	50	65	**45**
All Durban outlets	28	37	45	53	65	**53**
All outlets	77	49	56	**62**	65	60

Region of retail outlet

The best estimator of the number of alien plant species in all Johannesburg (45) and Durban outlets (53) was MMMeans, with Bootstrap and Jack 2 being the lower and upper bound estimators. (Table 8.2, Appendix 6j and k). For 'All outlets' Jack 1 was the best estimator predicting all of the outlets to have 13 additional alien species. Bootstrap and Jack 2 estimated 'All outlets' to have a minimum of 56 and a maximum of 65 alien plant species in both markets and all of the MS combined. (Table 8.2, Appendix 6l). Similarity of alien plant species sold in traditional medicine markets and *muthi* shop outlets

Type of retail outlet

Seventy percent (14 species) of the alien plant species sold at Faraday market were also sold at the Warwick market (Table 8.3, 8.4 & 8.5). Both markets sold the same five invasive species: *Anredera cordifolia, Cinnamomum camphora, Hedychium gardnerianum, Opuntia ficus-indica* and *B. delagoense*. Both markets and all MS sold 57% (19) of the same species (Table 8.3 & 8.5), five of which were invader species. In addition, these species were also in common between both markets and all MS: *Acorus calamus, dumapansi, Glycyrrhiza glabra, Helicteres isora* (Table 8.5).

Table 8.3. Sorenson's similarity index indicating the percentage similarity in alien plant species sold at various outlets. Numbers in brackets represent the number of shared species between two outlets and 'S' refers to species richness/number per outlet. Number of traders interviewed is represented by 'n'. The outlets include TM markets and *muthi* shops (MS) in Johannesburg (JHB), Durban (DBN) and Pretoria(PTA).

	Faraday n=32 S=18	Warwick n=28 S=22	Both markets n=60 S=26	PTA MS n=4 S=18	JHB MS n=10 S=25	DBN MS n=3 S=27	All MS n=17 S=41	Indian owned MS n=9 S=34	Black owned MS n=8 S=16	All JHB outlets n=32 S=33	All DBN outlets n=28 S=37
Faraday		70 (14)	*	33 (6)	47 (10)	44 (10)	51 (15)	42 (11)	59 (10)	*	51 (14)
Warwick			*	40 (8)	43 (10)	49 (12)	54 (17)	50 (14)	53 (10)	58 (16)	*
Both markets				36 (8)	47 (12)	45 (12)	57 (19)	47 (14)	57 (12)	68 (20)	70 (22)
Pretoria MS					65 (14)	49 (11)	*	69 (18)	47 (8)	*	47 (13)
JHB MS						50 (13)	*	61 (18)	78 (16)	86 (25)	55 (17)
Durban MS							*	89 (27)	37 (8)	60 (18)	84 (27)
All MS								91 (34)	*	81 (30)	82 (32)
Indian MS									36 (9)	69 (23)	82 (29)
Black MS										65 (16)	45 (12)
All JHB outlets											66 (22)
All Durban outlets											

*Datasets that are a subset of the other.

Table 8.4. Summary of outlets which are most and least similar to each other in terms of alien plant species. Similarity was calculated by Sørenson's similarity index. The outlets include TM markets and *muthi* shops (MS) in Johannesburg (Jhb), Durban and Pretoria.

Outlet	Greatest similarity with:	Least similarity with:	Excludes comparison with:
Faraday	Warwick	Pretoria MS	Both markets; All Jhb outlets
Warwick	Faraday	Pretoria MS	Both markets; All Dbn outlets
Both markets	All Dbn outlets	Pretoria MS	
Pretoria MS	Indian MS	Faraday	All MS; All Jhb outlets
JHB MS	Black MS, Indian MS	Warwick	All MS; All Jhb outlets
Durban MS	Indian MS, All JHB outlets	Black MS	All MS; All Dbn outlets
All MS	Indian MS	Faraday	
Indian MS	Durban MS	Black MS	All MS
Black MS	Jhb MS	Indian MS	All MS
All Jhb outlets	Jhb MS	Warwick	
All Dbn outlets	Durban MS	Black MS	

Race of retail outlet owner

Black-owned MS had a very low species similarity with Indian-owned MS (36%) (Table 8.3 & 8.4). There were no invasive species that were sold at both Indian and Black-owned MS. However, several of the alien species that were in common between Indian and Black-owned MS were *A. calamus*, *dumapansi*, *H. isora*, *G. glabra* and Indian pearls (Table 8.5).

Region of retail outlet

Twenty two species (66%) were in common between all Johannesburg and Durban outlets (Table 8.3). Four invasive species were sold in both Johannesburg and Durban outlets (Table 8.5).

8.3.4 Species unique to a specific outlet

Type of retail outlet

Of the 49 alien plant species that were sold in both markets and all MS, only seven species were unique to the markets whereas 22 were exclusively sold in MS (Table 8.6). A few of

these alien plant species that were only sold in the markets include: *Macadamia* sp., *P. tithymaloides, S. mauritiana,* and *S. cylindrica* (Table 8.6).

Race of retail outlet owner

Indian-owned MS had a significantly greater number (15) of unique species compared to Black-owned MS (2), (t_{15}=-2.6; p=0.02) (Table 8.6). The two species that were unique to Black-owned MS were *Commelina benghalensis* and *Senna* sp. (Table 8.6).

Region of retail outlet

Durban MS had the most unique species (12), followed by Johannesburg and Pretoria MS that only sold five and two unique species respectively (Table 8.6). Durban MS and Johannesburg MS sold two invader species each (Table 8.6). Johannesburg MS also exclusively sold the following alien species: *A. heterophylla, O. robusta,* and *Senna* sp. *Cassia fistula* and '*ibande*' were only sold in Pretoria MS (Table 8.6).

8.3.5 **Frequency of species occurrence**

Type of retail outlet

Faraday market was the outlet that sold the highest percentage (33%) of uncommonly occurring alien species (Figure 8.3a). This means that three in every ten alien species sold at the Faraday market were rarely occurring.

Warwick and MS in Durban, Johannesburg and Pretoria sold a high proportion of alien species that were commonly and intermediately occurring in those outlets (Figure 8.3a). Both markets sold five alien plant species that had the highest species occurrence in both Faraday and Warwick markets (Table 8.7). Twelve alien plant species had very high occurrence in the all MS and some of them include: *G. glabra, H. isora* and *W. somnifera* (Table 8.7).

Table 8.5. Alien plant species common to different outlets, either traditional medicine markets or *muthi* shops (MS) outlets. Species in **bold** have an invasive status, and species that are declared weeds (Category 1) are marked with '*' and those species that are declared invaders (Category 2) are marked with "**".

Species common to both markets	**Species common to markets and MS**	**Species common to markets and Black-owned MS**	**Species common to markets and Indian-owned MS**	**Species common to Indian and Black-owned MS**	**Species common to Johannesburg and Durban overall**
Acorus calamus	*Acorus calamus*	*Acorus calamus*	*Acorus calamus*	*Acorus calamus*	*Acorus calamus*
Anredera cordifolia*	***Anredera cordifolia****	*Araucaria heterophylla*	***Anredera cordifolia****	*Cassia angustifolia*	***Anredera cordifolia****
Bryophyllum delagoense*	*Araucaria heterophylla*	*Coix lacryma-jobi*	*Bryophyllum* sp.	*Foeniculum vulgare* var.	*Bryophyllum* sp.
Cinnamomum camphora*	*Bryophyllum* sp.	*Foeniculum vulgare* var.	*Cassia fistula*	*Glycyrrhiza glabra*	*Cassia angustifolia*
Coix lacryma-jobi	*Cassia fistula*	*Glycyrrhiza glabra*	***Cinnamomum camphora****	*Helicteres isora*	***Cinnamomum camphora****
Eleutherine bulbosa	***Cinnamomum camphora****	*Helicteres isora*	*Eleutherine bulbosa*	*Melaleuca leucadendron*	*Coix lacryma-jobi*
Foeniculum vulgare var.	*Coix lacryma-jobi*	*Melaleuca leucadendron*	*Foeniculum vulgare* var.	*Withania somnifera*	*Curcuma longa*
Glycyrrhiza glabra	*Eleutherine bulbosa*	***Opuntia ficus-indica****	*Glycyrrhiza glabra*	*dumapansi*	*Eleutherine bulbosa*
Hedychium gardnerianum*	*Foeniculum vulgare* var.	*Opuntia robusta*	***Hedychium gardnerianum****	Indian pearls	*Foeniculum vulgare* var.
Helicteres isora	*Glycyrrhiza glabra*	***Ricinus communis****	*Helicteres isora*		*Glycyrrhiza glabra*
Melaleuca leucadendron	***Hedychium gardnerianum****	*Withania somnifera*	*Melaleuca leucadendron*		***Hedychium gardnerianum****
Opuntia ficus-indica*	*Helicteres isora*	*dumapansi*	*Withania somnifera*		*Helicteres isora*
Sansevieria cylindrica	*Melaleuca leucadendron*		*dumapansi*		*Melaleuca leucadendron*
dumapansi	***Opuntia ficus-indica****		*unukani oyikhambi*		***Opuntia ficus-indica****
	Opuntia robusta				*Sansevieria cylindrica*
	Ricinus communis*				*Terminalia chebula*
	Withania somnifera				*kamal kadi*; *kamal kachie*
	dumapansi				*dumapansi*
	unukani oyikhambi				*girmalasing*
					inderjow
					Indian pearls

Table 8.6. Alien plant species unique to type of retail outlet, or the region of a retail outlet or the race of the retail outlet owner. Numbers of unique species are in brackets. Species in **bold** have an invasive status.

Type of retail outlet		**Region of retail outlet**			**Race of retail outlet owner**	
Both markets (7)	All shops (22)	Durban MS (12)	Jhb MS (5)	Pta MS (2)	Indian-owned MS (15)	Black-owned MS (2)
Macadamia sp.	*Anacardium occidentale*	*Andrographis paniculata*	*Araucaria heterophylla*	*Cassia fistula*	*Anacardium occidentale*	*Commelina benghalensis*
Pedilanthus tithymaloides	*Andrographis paniculata*	*Areca catechu*	***Opuntia ficus-indica***	*ibande*	*Andrographis paniculata*	*Senna* sp.
Sansevieria cylindrica	*Areca catechu*	*Bryophyllum* sp.	*Opuntia robusta*		*Areca catechu*	
Sansevieria fasciata	*Brassica* sp.	***Cinnamomum camphora***	***Ricinus communis***		*Brassica* sp.	
Spilanthes mauritiana	*Cassia angustifolia*	*Eleutherine bulbosa*	*Senna* sp.		*Cinnamomum* sp.	
inhlanhla emhlophe	*Cinnamomum* sp.	***Hedychium gardnerianum***			*Coriandrum sativum*	
iphengula	*Commelina benghalensis*	*Mimosa pudica* var.			*Curcuma longa*	
	Coriandrum sativum	*Platycarpha* sp.			*Mimosa pudica* var.	
	Curcuma longa	*avalkadle*			*Platycarpha* sp.	
	Mimosa pudica var.	*kachka*			*Quercus infectoria*	
	Platycarpha sp.	*kapoor kachi*			*Terminalia chebula*	
	Quercus infectoria	*unukani oyikhambi*			*avalkadle*	
	Senna sp.				*kachka*	
	Terminalia chebula				*kamal kadi*	
	avalkadle				*kapoor kachi*	
	girmalasing					
	ibande					
	inderjow					
	Indian pearls					
	kachka					
	kamal kadi					
	kapoor kachi					

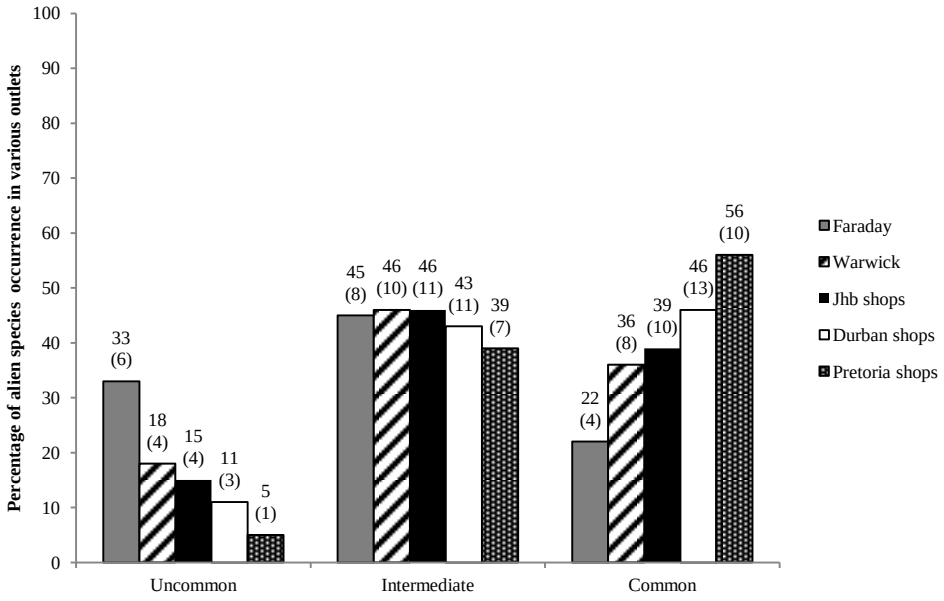
Race of retail outlet owner

A large proportion of alien plant species sold in Indian and Black-owned MS were of common and intermediate occurrence (Figure 8.3b). The alien plant species that were found most commonly occurring in the Indian-owned MS were *C. angustifolia, G. glabra, dumapansi, W. somnifera* and *H. isora*. *Glycyrrhiza glabra* and *H. isora* were also found commonly occurring in Black-owned MS (Table 8.7).

Region of retail outlet

All outlets had a high percentage of alien species that were of intermediate occurrence (54%) followed by 30% of species of uncommon occurrence (Figure 8.3b). Some of the species that had the highest frequency in all outlets included *A. calamus,* occurring 31 times followed by *H. isora, G. glabra* and *W. somnifera* (Table 8.7).

(a)



(b)

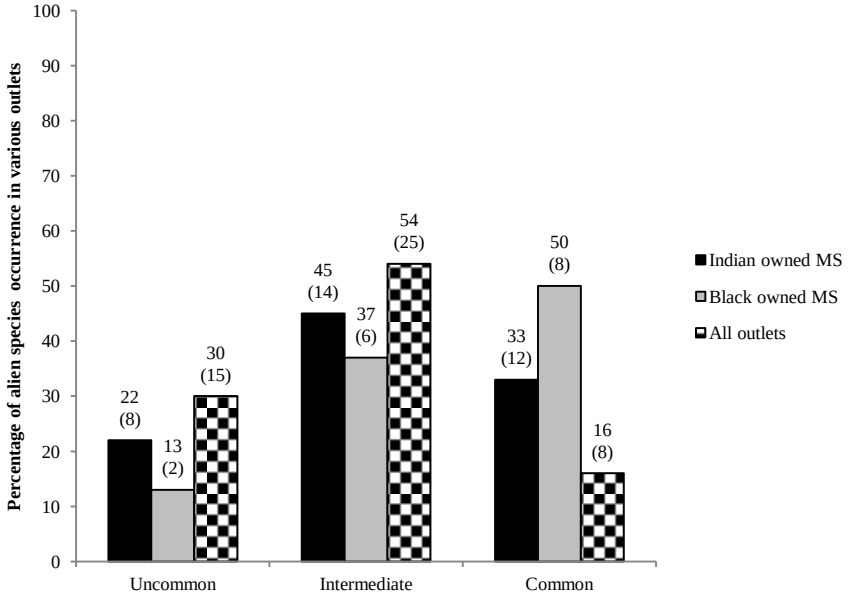


Figure 8.3. Rarity and commonness of alien species represented as percentage and number of species (in brackets), sold in various outlets reflecting the probability of alien species appearing in South Africa. Rarity is referred to as 'uncommon' in the figures above. Outlets include: (a) Faraday and Warwick traditional medicine markets, and Johannesburg (Jhb), Durban and Pretoria *muthi* shops (MS), (b) Indian and Black-owned MS and all outlets.

Table 8.7. Alien species that were of very frequent (common) occurrence in various outlets. Number of alien plant species were objectively chosen by the categories of common, intermediate and uncommon demonstrated in Figure 8.3.

Both markets	All MS	Black-owned MS	Indian-owned MS	All outlets
Acorus calamus	*Glycyrrhiza glabra*	*Coix lacryma-jobi*	*Cassia angustifolia*	*Acorus calamus*
Helicteres isora	*Cassia angustifolia*	*Glycyrrhiza glabra*	*Glycyrrhiza glabra*	*Helicteres isora*
Hedychium gardnerianum	*Helicteres isora*	*Acorus calamus*	*dumapansi*	*Glycyrrhiza glabra*
Glycyrrhiza glabra	*Withania somnifera*	*Foeniculum vulgare* var.	*Withania somnifera*	*Withania somnifera*
Melaleuca leucadendron	*dumapansi*	*Helicteres isora*	*Helicteres isora*	*Foeniculum vulgare* var.
	Acorus calamus	*Melaleuca leucadendron*	*Curcuma longa*	*Melaleuca leucadendron*
	Foeniculum vulgare var.	*Opuntia robusta*	*Acorus calamus*	*Hedychium gardnerianum*
	Curcuma longa	*Ricinus communis* var. *communis*	*Foeniculum vulgare* var.	*dumapansi*
	Indian pearls		*Terminalia chebula*	
	Coix lacryma-jobi		*Anredera cordifolia*	
	Melaleuca leucadendron		*Brassica* sp.	
	Terminalia chebula		*Cinnamomum* sp.	

8.4 Discussion

8.4.1 **Sampling sufficiency for the number of studies reviewed for the literature review**

The reviewing of 40 studies and the results from this study resulted in 320 alien species being recorded as used for traditional medicine in South Africa. The decrease in the rate of new alien plant species being recorded per reviewed study, suggest that the number of studies reviewed was sufficient in estimating the number of alien plant species that are used in South Africa. However, the curve did not reach an asymptote, therefore the total of alien plant species used in South Africa may exceed well over 350 species.

8.4.2 **Sampling sufficiency of the number of traders interviewed for this study**

Type of retail outlet

The point at which the species accumulation curve "*flattens, indicates a minimum viable sample size on which species richness or diversity should be based*" (Chiarucci *et al.*, 2003; Williams *et al.*, 2005a). Therefore, since the species accumulation curve for 'both markets' reached an asymptote, this indicates that an ample number of market traders were interviewed (Figure 8.2a). No asymptote was reached for the Durban and Pretoria *muthi* shop curves, which would indicate that more shops should have been surveyed, resulting in more alien plant species being recorded (Figure 8.2a).

Market traders generally keep fewer species per trader compared to shops and for this reason, more market traders have to be interviewed in order to get a good representation of species richness in the trade (Williams *et al.*, 2005a). This was observed in this study where the number of traders interviewed in both markets was 60, and the number of shop traders interviewed was 17.

Race of retail outlet owner

The sampling of Indian and Black-owned shops was sufficient because the number of alien species recorded after the last trader was interviewed was 0 and 1 respectively and the species accumulation curves started flattening out (Figure 8.2).

Region of retail outlet

Surveying of Johannesburg and Durban outlets proved to be sufficient as the species accumulation curves started reaching asymptotes. In addition, sampling of all outlets for this study was sufficient, indicated by the species accumulation curve starting to flatten and the rate of new alien plant species being recorded dropping to only one (Figure 8.2b). Even though an adequate number of market and shop traders were interviewed in this study and species accumulation curves reached asymptotes, Williams *et al.* (2007b), explains that there is doubt that species accumulation curves will ever reach a complete asymptote. This is because the diversity of plant species sold in the *muthi* markets and shops is high, and the area from where the species are harvested is extensive and continuously spreading (Williams *et al.*, 2007b). Considering this it can be stated that the sampling of outlets in this study was sufficient.

8.4.3 Observed species richness and diversity of alien plant species sold in the South African *muthi* trade

Type of retail outlet

Amongst the markets, Warwick had a greater diversity of alien species compared to Faraday. One reason for this is that there are considerably more traders at the Warwick market compared to the Faraday market. Warwick market also supplies a large majority but not all plant species to the Faraday market (Williams *et al.*, 2007a). Most of the plant species sold at the Warwick market are harvested in KZN which are then sold at the Warwick market (Williams, 1992; Williams, 1997).

It is interesting that the number and diversity of alien species sold at Faraday increased slightly from a previous study done in 2001 (Table 8.8). Eighteen alien species were recorded at Faraday in 2011, whereas 15 alien species were recorded in 2001. Although the whole of Faraday market was assessed in this study, fewer traders at Faraday sold alien plant species in 2001 compared to 2011.

With both markets combined, it was found that 26 alien plant species were sold between the traders in the market (Table 8.1). The reasons why shops sell a larger number of alien plant species are discussed in Chapter 3. These same reasons explain why shops sell a greater

diversity of alien plant species compared to markets. Further explanation on how this is affected by the race and region of the retail outlet was also expanded on in Chapter 3.

Table 8.8. Comparison of species richness (S) and mean number of alien plant species sold between surveys conducted in *muthi* shops (MS) in 1994 and 2011, as well as market surveys conducted in 2001 and 2011. n = Number of traders interviewed is represented by 'n' and the numbers in brackets are the total number of traders.

Outlet:	Muthi shops				Faraday market	
Year:	1994*		2011		2001*	2011
Race:	Black-owned MS	Indian-owned MS	Black-owned MS	Indian-owned MS	Black Traders	
Measure:	n=25	n=20	n=8	n=9	n=44 (100)	n=32 (198)
Species richness (S)	19	19	16	34	15	18
Mean S per trader ± SD	14.1±4.3	16.3±3.1	11.6±4.1	25.9±8.7	10.9±3.6	12.4±44

* Based on V.L. Williams unpublished data

The higher evenness values in Durban outlets compared to Johannesburg outlets indicate that a majority of the alien plant species sold in Durban outlets were equally present with very few species being dominant. Nonetheless, all of the outlets had high evenness values (between 0.86-0.98) which means that at most of the outlets, the alien species sold were equally prevalent and, all else equals, have the same chance of spreading.

8.4.4 **Estimating species richness**

Type of retail outlet

Faraday and Warwick markets were estimated to have 26 and 27 alien species respectively. These estimations were eight and five alien plant species more than what was recorded at these markets (Table 8.2). These species richness estimations are likely due to both Faraday and Warwick selling many similar species from the same sources. It is likely that Faraday may even sell the same 27 alien species as sold at Warwick, because the Faraday traders buy their stock from Warwick. In addition, alien species that were sold at Warwick could have been overlooked or missed at Faraday and vice versa because the Faraday and Warwick market surveys were conducted as snap shots and not over a longer period. Therefore if surveys of both Faraday and Warwick markets were conducted over several months, they could have been found to sell 26 and 27 alien species respectively.

Both markets were estimated by Jack 1 to sell 29 alien plant species, which was three more than recorded (Table 8.2); these three species could be found in more surveys of the markets. In addition, as there is already a flow of imported species from *muthi* shops to the markets, as observed in this study, it is possible that through time more imported alien plant species could be sold in the markets.

All *muthi* shops sold 41 alien species and were estimated to sell another 18 species (Table 8.2). There were eight alien plant species that were not sold in any of the shops but were sold in the markets. Since imported and naturalised species are bought and sold between shops and markets, there is definite possibility that 49 alien plant species may be recorded in all shops, which is the total of alien species recorded in the whole study.

Race of retail outlet owner

Estimations of species richness for Indian-owned shops were similar to the estimation made for all MS as mentioned above. That is, Indian-owned shops were estimated to have 14 additional alien plant species above the 34 that were recorded in all of the Indian-owned MS. These additional 14 alien species would add up to a total of 48 species, which is close to the number of alien species recorded in all of the outlets (49) (Table 8.2). These 14 alien species could have been overlooked during the surveys. Indian-owned MS sell a large number of imported species and smaller percentage of naturalised species which they buy from the markets. This suggests that, through years to come, Indian-owned shops could also sell the additional naturalised alien plant species that are sold in the markets.

Black-owned MS on the other hand were predicted to only sell five more alien species, totalling 21 alien plant species (Table 8.2). These five additional alien species might have been found if further sampling took place. Black-owned shops sold a majority (10) of naturalised species and a few (6) imported species. Since Black-owned shops obtained species from both Indian-owned shops and from the markets, it is possible that they may buy more alien species from either outlet possibly due to a demand for other alien species or a change in customer race.

Region of retail outlet

Johannesburg outlets were estimated to sell 45 alien plant species, 12 more species than was observed (Table 8.2). This total is close to the total number of species observed in all of the

outlets and since there is a flow of alien plant species from Warwick to Faraday and from Durban MS and Indian MS to Johannesburg MS, it is probable that Johannesburg may sell up to 45 alien plant species.

Sixteen more alien plant species were predicted to occur in Durban outlets, which is four more species than was observed in all of the outlets (Table 8.2). As observed in this study, Durban is the city where a large majority of the alien plant species are sourced from, i.e. from Warwick (where species are harvested in the greater KZN) and Indian-owned MS (who obtain imported species from the wholesalers in Durban). The potential area from which species in the general *muthi* trade are harvested is extensive (Williams *et al.*, 2007b), therefore just concerning the naturalised alien species that are sold in Durban, there may be a few alien plant species that were completely missed during the surveys. Lastly all of the outlets combined were estimated to sell 62 alien plant species and once again, this is possible due to the same reasons mentioned above for the Durban outlets.

8.4.5 Similarity of alien plant species sold in traditional medicine markets and *muthi* shop outlets

Type of retail outlet

Faraday and Warwick had a large percentage (70%) of the same alien species because Faraday market gets a large proportion of its stock from the Warwick market, which in turn is predominantly harvested in KZN (Table 8.3). This indicates that there is a flow of species from Warwick (Durban) to Faraday (Johannesburg). A general characteristic of a market is that they sell plant species that are harvested in surrounding areas (Mander, 1998a; Botha *et al.*, 2004a) and in this study, Warwick sold alien plant species that were harvested in municipal districts in KZN. Both markets stocked five out of the six invasive alien plant species recorded in this study, including: *A. cordifolia, C. camphora, H. gardnerianum, O. ficus-indica* and *B. delagoense* (Table 8.5).

Since both markets sell largely the same alien plant species, and also the same five invasive alien species, this suggests that both Faraday and Warwick markets play an equal role in potentially spreading these five invasive species in South Africa as well as any other alien species sold in the markets. The markets also both stocked *dumapansi, H. isora* and *G. glabra*, which were all bought from Indian-owned shops and imported from India as found in

this study. Fortunately these three imported species are not sold as viable propagules and therefore will not spread in South Africa.

Markets and all shops sold almost 60% of the same alien plant species, which included five invasive species and several imported alien plant species. A majority of the same alien species were sold between all shops and the markets because these species came from the same source. This infers that both types of outlets may cause these similar species to further spread in South Africa.

Race of retail outlet owner

Both Black and Indian traders had many alien species in common. The reasons for this are: historical interactions between Indian and Black traders, a common source of the alien plant species (imported and naturalised) and the overlap in race of customers.

Firstly, historical interactions between Black and Indian workers resulted in a sharing of traditional medicinal knowledge (Flint, 2006). For this reason many similar plant species are still used by both races today. Then, the naturalised alien species sold in this study by both races are predominantly harvested in KZN while the imported alien plant species are ultimately obtained through the same wholesaler in Durban who directly imports these species from India. Finally, traders from both races had predominantly Black customers with a small proportion of Indian, White and Coloured customers.

Region of retail outlet

Johannesburg and Durban sold a large proportion of the same species because the sources of the species were the same and most probably because Zulu's residing in both Gauteng and KZN demand the same medicine. Gauteng has been cited as the province with the largest urban concentration of Zulu people and KZN has been reported as the province with the largest rural concentration of Zulu people (www.sahistory.org.za, 2013).

8.4.6 Species unique to a specific outlet

Type of retail outlet

Muthi shops had a large number (22) of alien plant species that were unique to them and only a few (7) species were unique to the markets. Most of the plant species that were unique to

only *muthi* shops were imported from India and those unique to markets were harvested in South Africa. Eighty four percent of the alien plant species recorded in this study were sold in shops, meaning that one could go to a shop and find almost all of the alien plant species sold in the herbal medicine trade. Cunningham (1988) explains that shop owners need to sell scarce species, as they offer a diversity of plants to a variety of clientele, such as herbalists, diviners, market traders and traditional medicine users and therefore function as a wholesaler and retailer. Similarly, markets are also wholesalers as they sell naturalised alien plant species to shop owners. Markets function as retailers in that they sell imported or naturalised alien species to the users (Williams, 2003).

Race of retail outlet owner

Indian-owned shops had a greater selection of unique alien plant species compared to Black-owned shops which only had two unique alien plant species (Table 8.6). The alien species that were unique to both Indian and Black-owned shops were not sold in any of the markets, which indicates that Indian and Black-owned shops are 'general dealer' stores regarding these specific alien plant species.

The customer base of both Indian and Black-owned *muthi* shops differed, in that the former had approximately 30% Indian, White and Coloured customers (S. Dorasammy pers. comm., 2011; A.M Khan pers. comm., 2011), and 70% Black customers, whereas the latter were observed to have a 99% Black client base and 1% Indian, White and Coloured client base.

Region of retail outlet

Despite the similarities in alien plant species sold between Durban, Johannesburg and Pretoria shops, is it interesting that there were however unique alien plants sold in each city (Table 8.6). All the species that were unique to Johannesburg and Pretoria shops were naturalised alien species, excluding *Senna* sp. and *ibande* respectively. The source of *Senna* sp. was not given by the trader selling this species and the source of *ibande* is in Zimbabwe. Durban shops sell the largest range of alien plant species.

Amongst the shops, Durban MS had the highest number of unique species, followed by Johannesburg and Pretoria only having a few unique species. Shops in Durban sold more alien plant species compared to the others because it was observed that they are the main

wholesalers to other shops and have a history of being in the *muthi* trade for many years (Cooppan, 2010).

8.4.7 **Frequency of species occurrence**

Type of retail outlet

Faraday market sold a large proportion of alien plant species that were of low and intermediate occurrence compared to Warwick market that sold more alien species that had high and common occurrences (Figure 8.3a). This means that the alien species sold at Warwick market were frequently available amongst the traders in the whole Warwick market. Common species are those that the traders stock and sell more frequently relative to other species, at relatively larger volumes (Williams, 1997; Williams *et al.*, 2000).

All of the shops sold mostly alien plant species that were of common and intermediate occurrence (Figure 8.3a). This indicates that a large proportion of the alien plant species were frequently available amongst the shops in the different cities, i.e. Johannesburg, Durban and Pretoria.

Traditional medicine markets generally stock larger quantities of plant products (mean mass in kilograms) per individual species compared to the shops. This was observed in this study as well as by Williams *et al.* (2007a). Therefore even though shops sold a greater richness of alien species, markets sold larger quantities and therefore could have a greater impact in spreading alien plant species in South Africa.

Species of common occurrence are indicator species that are usually those in high demand by resources users. Commonly used indigenous species are at risk of overexploitation and population decline (Williams *et al.*, 2005a). In the case of alien plant species, overexploitation could be a positive thing, as this will inhibit these frequently sold species from spreading and possibly becoming a problem or invasive in the future, but may unfortunately promote planting in order to conserve various species.

Race of retail outlet owner

Indian and Black-owned *muthi* shops alike sold alien plant species that were of common and intermediate occurrence (Figure 8.3b). This indicates that a large proportion of alien species

sold in Indian and Black-owned shops are frequently available in different Indian and Black-owned shops and are in demand by a large proportion of Black and Indian customers and also by the few White and Coloured customers.

Region of retail outlet

Most of the alien plant species sold in all of the outlets had between intermediate and "rare" (uncommon) occurrence. This means that alien species were not sold consistently throughout all of the outlets in this study (Figure 8.3b). The four alien plant species that were found most frequently occurring in the *muthi* markets and shops include: *A. calamus*, *H. isora*, *G. glabra* and *W. somnifera.*

8.5 Conclusion

This study observed that a large proportion (54%) of the alien plant species in this study had intermediate occurrence, meaning that many of the alien species were observed regularly in the shops and *muthi* markets. Furthermore, the following eight alien species were dominant in most of the outlets and could possibly become a problem. These species include: *A. calamus, H. isora, G. glabra, W. somnifera, F. vulgare*, *M. leucadendron, H. gardnerianum* and *dumapansi*. Lastly 30% of the alien species in this study were observed only once or twice.

It was observed that shops sold more alien plant species compared to markets, so much that the shops, especially Indian-owned, can be referred to as general-dealers in alien plant species. This is because they sold a large range of both imported and naturalised alien species. In addition, Warwick market sold more alien plant species compared to the Faraday market. Similarly, Durban shops were more species rich compared to Johannesburg and Pretoria. Various outlets sold different number of alien plant species as a result of the location of the outlet, source of the alien plant species and the history of Indian migration to KZN from India.

The species richness estimator Jack 1 was generally the best estimator, approximating between 3 to18 additional alien plant species that could have been recorded at various outlets. The approximations made by the estimators are plausible, due to the flow of alien species from markets to shops and vice versa which could increase over time. Since there is a flow of plant species between the various outlets, many of the outlets sell the same alien species.

Sampling sufficiency, regarding the number of traders interviewed at each market and all MS combined, was adequate in representing the number of alien plant species sold in markets. However, surveying of the individual shops in Johannesburg, Durban and Pretoria were not adequate and could have more alien plant species that were not picked up in this study.

A large proportion of the same species were sold at Faraday and Warwick markets, as well as both markets and all shops. The main reason for this was because many of the species sold came from the same source and because customers demand the same alien plant species. On the other hand, Indian and black-owned shops did not sell many of the same species.

All of the outlets in this study sold unique species. Durban MS, Indian-owned MS and all MS in general sold more unique species compared to other shops and markets. This indicates that *muthi* shops are so called ‘general dealers’ as they sell a range of alien species and also alien species that are not available at any other outlet.

CHAPTER 9: INDIGENOUS AND ALIEN ETHNOMEDICINAL TAXA (FAMILIES AND GENERA) USED IN SOUTH AFRICA

9.1 Introduction

Traditional medicine is used by many people in South Africa, irrespective of their age, education or class (Dold and Cocks, 2002; Mander *et al.*, 2007). In 2007 the number of plant species used in South Africa was reported as at least 771 plant species (Mander *et al.*, 2007), but this figure was recently updated to 2062 indigenous plant species (Williams *et al.*, 2013). Understanding the extent of the medicinal trade regarding which alien and indigenous plant species are sold is valuable. This is because it not only indicates the traditional knowledge of the traders and customers that sell and use it but it also indicates medicinal properties of plant species that might not have been discovered by modern medicine yet.

Plant families used for medicinal purposes are often reported in ethnobotanical studies; this information provides insight into the families most used (Dold and Cocks, 2000; Williams *et al.*, 2000; Botha *et al.*, 2001). Mack *et al.*, (2000) reports that the worst invasive plants worldwide belong to relatively few families (Asteraceae, Poaceae) and genera (*Acacia, Mimosa, Cyperus*) and that based on a list of morphological and ecological characteristics, particular *Pine* sp. can be successfully predicted as invasive species in South Africa. Furthermore, Richardson and Pyšek (2006) explain that related to the global species pool, the following families are consistently over-represented in invasive-alien floras: Amaranthaceae, Brassicaceae, Convolvulaceae, Fabaceae, Malvaceae, Poaceae, Papaveraceae, and Polygonaceae. The families of alien and also indigenous plant species used for *muthi* are discussed in this chapter to examine patterns of use of invasive species, and probability of invasion through the *muthi* trade.

9.2 Methods

To determine if similar families were used for traditional medicine in Johannesburg, Durban and Pretoria compared to the whole of South Africa, a Spearman's rank correlation was conducted which compared the number of species per family as recorded in this study with those in the 40 reviewed studies.

The alien species cited in the literature review were not all traded as some have only been recorded as being used. On the other hand, those species that are traded are also used, because customers buy species from a market or *muthi* shop and use them. Studies that cited alien species that were only used for traditional medicine and also those studies that cited species that were traded were counted. These numbers were added to the number of indigenous plant species in South Africa recorded by Williams *et al.* (2013) that were only used for TM and those that were traded. These numbers were added in order to calculate the total number of alien and indigenous plant species that are used and traded in South Africa.

The number of species per family in the reviewed studies and the indigenous plant species recorded in Williams *et al.* (2013) were compared to determine if similar indigenous and alien plant species in terms of family are used. In order to compare how many of the same families were used and traded between indigenous species and alien species, the Jaccard classic index of similarity was calculated. The formula to calculate the Jaccard classic was used from Magurran, (1988).

9.3 Results

9.3.1 **Number of alien ethnomedicinal taxa (families and genera) used in South Africa**

Three hundred and twenty ethnomedicinal plant species from 77 families and 220 genera were recorded in use in South Africa from studies in the literature review. The families most frequently used for traditional medicine in terms of number of species were: Asteraceae (44 species), Fabaceae (36), Poaceae (22) and Solanaceae (17) (Figure 9.1). Species from 25 families and 32 genera were recorded in Johannesburg, Durban and Pretoria *muthi* shops and Faraday and Warwick markets during this study. This study recorded one new family, Arecaceae, that was not yet recorded in the trade (Appendix 4). Taxa from Fabaceae were most commonly recorded in this study (5 species), and seven families with only two species each were recorded, namely: Asteraceae, Apiaceae, Cactaceae, Crassulaceae, Dracaenaceae, Lauraceae and Zingiberaceae (Figure 9.2).

A Spearman rank correlation found a weak negative correlation between the number of species per family in this study compared to the number of species per family from the studies in the literature review (ρ=-0.402 at p <0.050). Hence, a slightly different suite of species are used compared to the species that are traded.

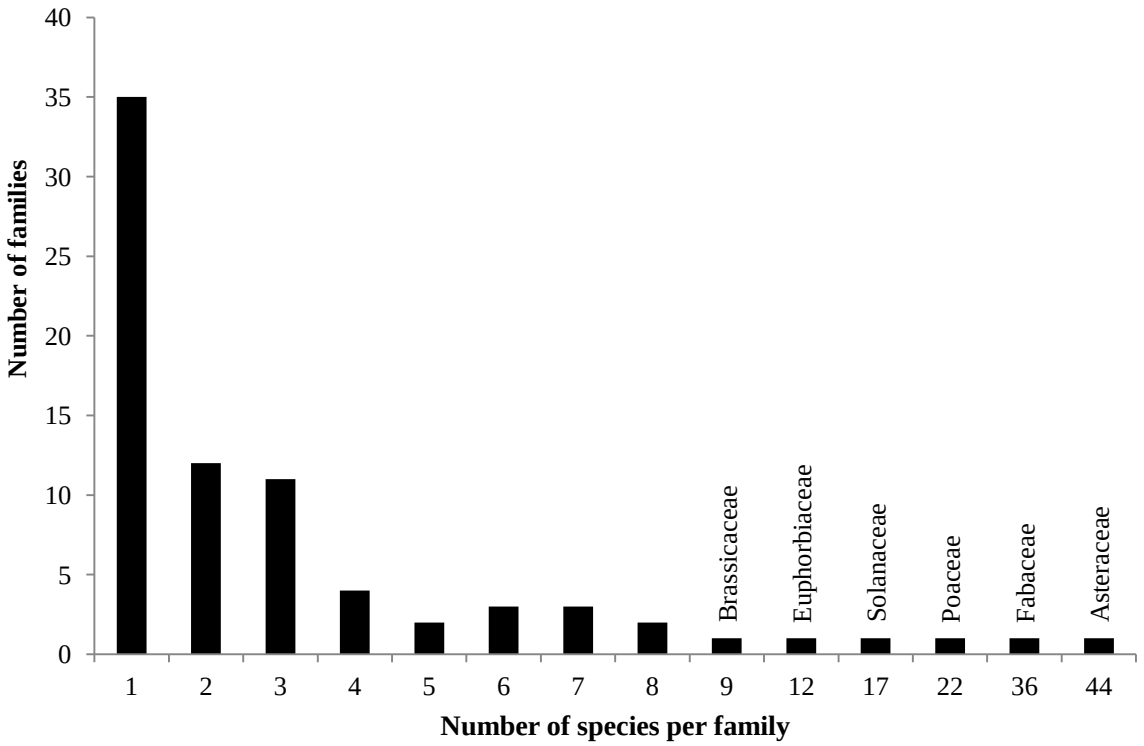


Figure 9.1. The number plant species per family used for traditional medicine in South Africa. Based on data from 41 studies published between 1895 and 2011.

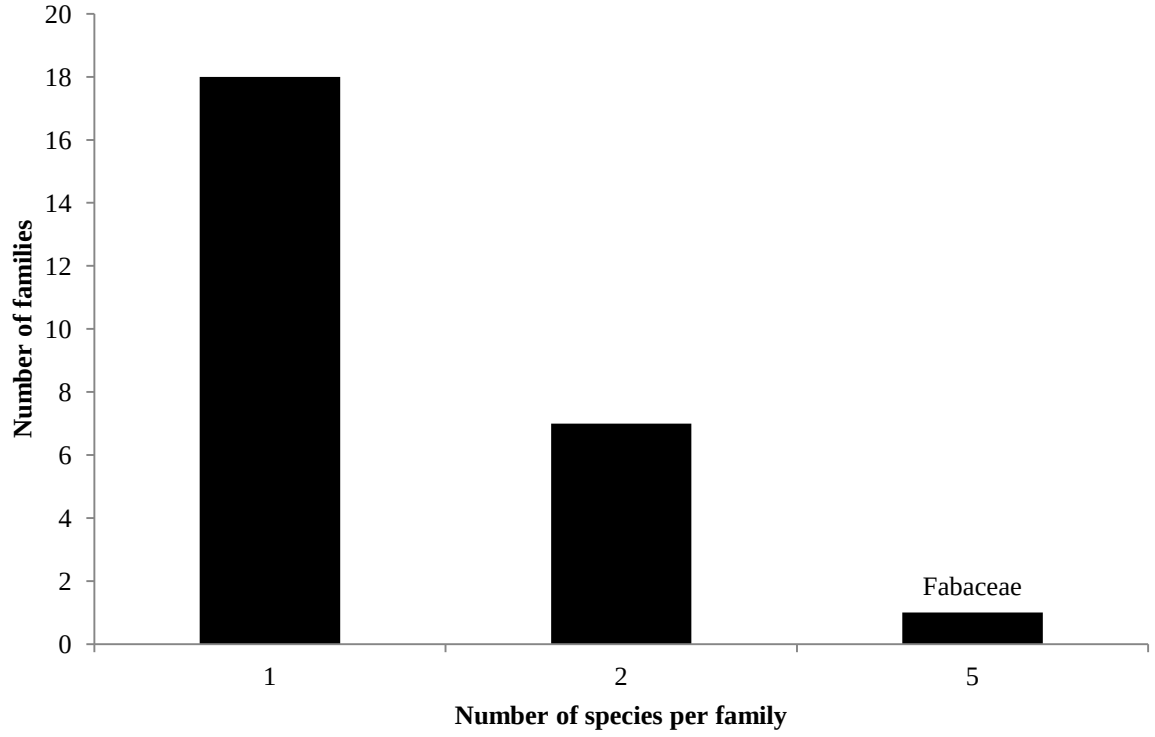


Figure 9.2. The number of plant species per family sold in traditional medicine markets and shop outlets in South Africa recorded in this study.

9.3.2 **Alien and indigenous families used (not traded) for traditional medicine**

Two hundred and forty three families, including alien and indigenous plant species, are used and/or sold in South Africa. A Spearman rank correlation was conducted on the ranks of the families in terms of the number of species per family between the studies from this literature review and Williams *et al.* (2013). A weak inverse relationship (ρ=-0.443, $p < 0.050$) was found between the two datasets indicating that, with the exception of Fabaceae, there is little correlation between the alien and indigenous plant families most likely to be used.

Of the 243 families, 58 families were common between the two datasets (alien and indigenous), and 185 families were unique to either the alien or the indigenous ethnomedicinal flora. When the number of species per family from the 58 common families were compared between the two datasets, there was a positive correlation (ρ=-0.402 at p <0.050) indicating the alien and indigenous flora have similarly high ranked families in terms of the number of species. When the top 8 of the 58 common families were compared, a much stronger correlation was shown (ρ=0.888 at p <0.050) – hence indicating that similar large families are more commonly used. When the remaining 50 families were compared, there was a very weak correlation (ρ=0.03 and p <0.050), indicating no relationship between the number of species per family for the alien or indigenous datasets. Of the 10 largest indigenous families and the 11 largest alien families, the following were common: Asteraceae, Fabaceae, Lamiaceae and Euphorbiaceae.

A similarity index on the presence and absence of families between the reviewed studies, species from this study and Williams *et al.* (2013) had a Jaccard classic result of 0.313. The Jaccard classic result indicates that between the two datasets the families were 31.3% similar or 68.7% dissimilar. The families that were similar between the two datasets were mentioned in the previous paragraph.

9.4 Discussion

9.4.1 **Number of alien families, genera and species per family sold for traditional medicine in South Africa**

The 320 alien plant species used and traded as recorded in this literature review belong to 77 families and 220 genera, with Asteraceae, Fabaceae, Poaceae and Solanaceae being the

families with the largest number of alien species per family that are used for traditional medicine. The largest alien families sold differs to that of indigenous plant species sold, which recorded the Fabaceae, Liliaceae *sensu lato*, Asteraceae, Euphorbiaceae and Rubiaceae as the largest indigenous plant families traded (Williams *et al.*, 2001).

Fabaceae, Asteraceae, Myrtaceae and Solanaceae are the largest families of invasive alien plant species occurring in South Africa (Henderson, 2001b; Klein, 2011). These four families already have species that have become established and are invasive in South Africa. Pyšek (1998) mentions that the most successful families have specific features that can contribute to the success of their invasiveness. Richardson and Pyšek (2006) explains that some species are more likely to be invasive if other species in the same family are already naturalized in the same area, because they share some level of preadaptation to the conditions of the invaded area with their congeners. Therefore since some invasive alien plant species belonging to Asteraceae, Fabaceae and Solanaceae are already being used for *muthi* in South Africa, other alien species in the same families may potentially also become invasive as explained by Richardson and Pyšek (2006).

Species sold in the *muthi* shops and markets are transported (Williams *et al.*, 2000), used (Van Wyk *et al.*, 2009), planted, (Williams, 1997), and discarded, (Mander *et al.*, 2007) therefore creating the potential for any species to spread, grow and possibly become established in South Africa (Williams, 1997; Mander, 1998a; Nesvåg, 1999; Mander *et al.*, 2007; Williams *et al.*, 2007a; Van Wyk *et al.*, 2009)

This study found 25 families and 32 genera were sold in Johannesburg, Durban and Pretoria, with Fabaceae and Asteraceae having the highest number of species per family. No correlation was found between the studies in the literature review and this study in terms of the number of species per family. This is because the literature review covered studies conducted in a more widespread area and thus resulted in many more families observed, with many more species per genus. This study, however, shows that in several instances marginally more species were observed in some families compared to that of the literature review. This resulted in a negligible weak negative correlation.

Differences in observed species per family between this study and the literature review could probably be ascribed to the difference in availability of plant species to traders. Most alien species in this study were either harvested or purchased in KZN. This is in contrast to most of the reviewed studies where species were harvested in different locations across the provinces of South Africa including Limpopo, Mpumalanga, Western Cape as well as KZN.

9.4.2 **Combined number of alien and indigenous plant species used for traditional medicine in South Africa, whether traded or not**

The results from this study, combined with the literature review, as well as the results of Williams *et al*. (2013), indicate that at least 2386 plant species have been used for TM in South Africa (Table 9.1). Sixty eight percent of this total refers to species that are used but not traded, while 32% of the species are both sold and used (Table 9.1). It could be assumed that species which are only used for TM and not sold will probably not be transported and spread as much as those species that are sold. However, this is not the case, since species which are only used may be used locally within communities and transported within and between villages. It is also possible that they could be that prevalent in the veld and that there is no need to harvest and sell them. Species that are only used for TM are usually harvested close to where the users reside (Dold and Cocks, 2000; Thring and Weitz, 2006). Sold species on the other hand, are transported from the area in which they are harvested to the markets or shops and then transported again to where the customer resides (Nesvåg, 1999; Grace, 2002). Therefore, all alien plant species that are used for *muthi* have the potential to spread and potentially become invasive if the species have invasive traits.

Table 9.1. Number of alien and indigenous plant species used and sold for traditional medicine in South Africa. The alien plant species are recorded from the literature review, and the indigenous plant species were recorded by Williams *et al.* (2013).

Plant species	**Used**	**Sold**	**Total**
Alien	204	116	320 (13%)
Indigenous	1406	656	2062 (87%)
Total	1612 (68%)	774 (32%)	2382

9.4.3 **Alien and indigenous families that are used for traditional medicine**

The entire South African trade in alien and indigenous medicinal plant species is made up of 243 families. This number of families is an increase from 215 families reported by Arnold *et al.* (2002). The families with the most number of species that are used and/or sold for *muthi* in South Africa are Asteraceae, Fabaceae, Apocynaceae and Asphodelaceae (Williams *et al.* 2013). Comparing the alien and indigenous families that are sold it is therefore clear that Asteraceae and Fabaceae are the families with the most number of alien and indigenous plant species used for traditional medicine in South Africa. Asteraceae and Fabaceae contain natural chemicals of medicinal importance (Tene *et al.*, 2007) – a possible reason why alien and indigenous plant species from these families are used for TM (Grace *et al.*, 2004).

Fifty eight families were common between the studies in the literature review and Williams *et al.* (2013), of which there were eight families that had high numbers of alien and indigenous species per family. The top eight families in terms of number of species used were Asteraceae, Fabaceae, Apocynaceae, Lamiaceae, Euphorbiaceae, Malvaceae, Rubiaceae and Amaryllidaceae. Almost 70% of the families cited in the reviewed studies were dissimilar to the families cited in Williams *et al.* (2013), indicating that alien families are used due to them having different medical properties compared to indigenous families.

9.5 Conclusion

The plant families containing the largest number of species used for traditional medicine include: Asteraceae, Fabaceae, Poaceae and Solanaceae. Alien plant species that belong to the families Asteraceae, Fabaceae and Solanaceae may have a greater chance of becoming invasive in South Africa, due to invasive traits in these families. Different families were used as recorded in this study and in the literature review due to different geographical areas and thus differences in the availability of plant species.

This study found that a total of 2386 indigenous and alien medicinal plant species are used in South Africa. Asteraceae and Fabaceae were not only the largest alien families recorded, but these two families are also the largest in terms of indigenous species that are used for *muthi*. These two families are most probably used because of their medicinal properties. Even though these two families were found to be the most utilised amongst indigenous and alien plant species, this study found that very few families were commonly used between indigenous and alien species. This is probably due to the alien and indigenous families having different medicinal properties.

CHAPTER 10 - GENERAL DISCUSSION

This study shows that alien species sold in retail outlets (*muthi* shops or markets) are linked to the source of the alien plant species sold (harvested in South Africa or imported from India), the location of the retail outlet (Durban, Johannesburg, etc), history of Indian migrancy and traders in South Africa, the race of retail outlet owner (Black, Indian) who sell plants, and lastly the race of the customer buying the plant species. The race of the retail outlet owner plays an important role in determining which species are sold and imported, and affects the diversity of the species sold by each trader.

The trade of alien plant species between outlets is represented in Figure 10.1. Harvesters gather species from the veld and bring them to the markets. Market traders receive naturalised alien species from these harvesters. Market traders also purchase alien plant species which are imported from India, from Indian-owned shops. The Indian species are imported by a wholesaler (shaded black), and purchased by Indian-owned *muthi* shops. Indian and Black-owned shops purchase the alien plantw from the markets (indicated by the dark grey shading). In addition, Black-owned shops acquire Indian alien species from Indian-owned shops.

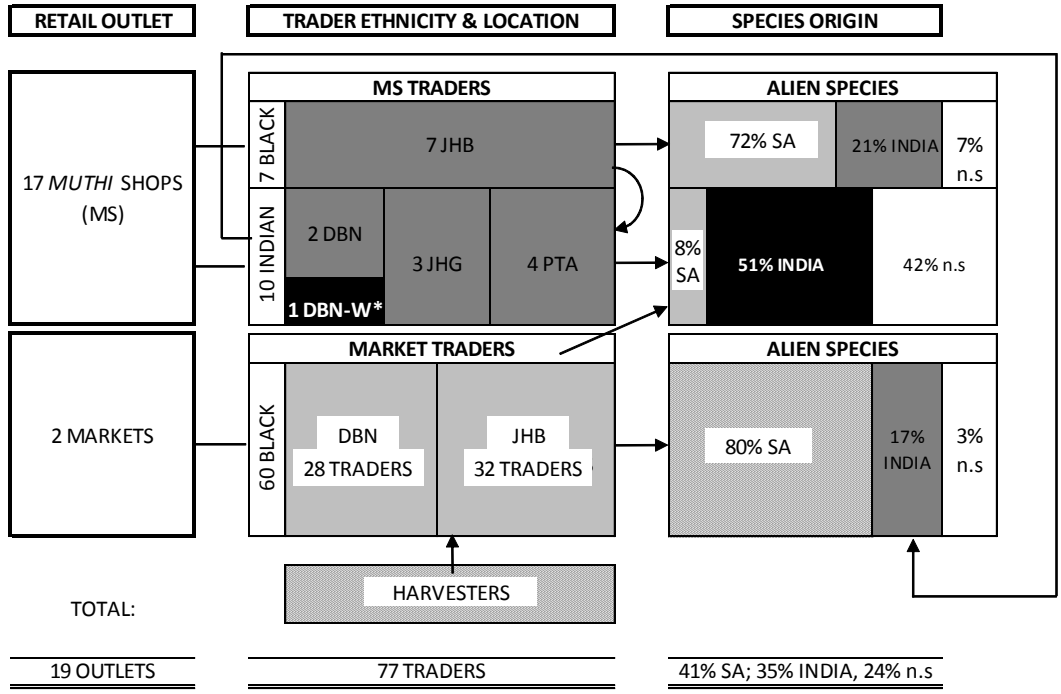


Figure 10.1. The relationship amongst market and *muthi* shop (MS) traders and their link to the alien plant species they sell. Shading is used to indicate where the traders obtain their alien species from. '*' refers to a wholesaler who is situated in Durban and imports alien species from India. The imported alien species are then purchased by Indian-owned MS. JHG=Johannesburg; DBN=Durban; PTA=Pretoria and n.s = not specified

10.1 Synthesis

This study found that a total of 49 alien plant species are sold in the Faraday and Warwick *muthi* shops markets and shops in Johannesburg, Durban and Pretoria. Furthermore, 320 alien plant species have been recorded as being used for medicine in South Africa. These 320 alien plant species belong to 77 families and 220 genera, with the largest families in terms of species per family being Asteraceae, Fabaceae, Poaceae and Solanaceae. The majority of these alien species originate from Asia suggesting that the introduction of alien plant species into South Africa from Asia has not been by chance.

A total of 2386 indigenous and alien plant species were calculated to be currently used/sold for traditional medicine in South Africa (based on Williams *et al.* 2013, this study and the literature review). Not all plant species that are used are sold in markets and shops. This study calculated that between 64-68% of alien and indigenous plant species are used but not traded. The remainder are sold in either markets or *muthi* shops, which in turn are also used by consumers of herbal medicines. Of the 2386 indigenous and exotic plant species belonging to 243 families, 13% are alien plants. This points out that the use of alien plant species only makes up a small portion of all the plant species used for TM. Identifying all the alien and indigenous plant species used in South Africa has proven to be valuable as it provides insight as to how extensive the trade in South Africa is.

Only eleven percent of the 320 alien plant species recorded are culinary species frequently used by many South African households. Since users of herbal medicines often use these culinary species and most households use these species for food, this means that the use of alien plant species has become common and has been incorporated into the lives of many South Africans.

In this study, the numbers and diversity of alien plant species sold at the various outlets, including *muthi* markets and shops, differed. Traditional medicine markets, Black-owned and Johannesburg shops all sold more naturalised alien plant species, compared to Indian-owned, Durban and Pretoria shops who sold more alien species directly imported from India. These differences in number and diversity of alien plant species are the result of a few factors. These factors include: difference in the sources of alien plant species sold, location of outlet, customer race and lastly the proportion of Indians in Durban.

It was estimated that there could be more alien plant species (3-18 alien species) occurring at the various outlets. The approximations made by species richness estimators seem probable as there is flow of plant species between the outlets, i.e. market traders buy imported alien species from *muthi* shops and also sell naturalised alien species to the shops. Because of this flow, some of the outlets sold similar alien plant species. In contrast, most of the outlets also sold alien species that were unique to that outlet, indicating that each outlet filled a specific niche in selling unique alien plant species to its customers.

The estimated volume of alien plant species sold in this study was calculated as 87 x 50kg-size bags (note: this does not equate to an equivalent mass), which is only a fraction of the volume of indigenous plant species traded (Mander, 1998b). Even though the total volume of alien plant species recorded in this study was much lower than indigenous plant species, this study found that five alien plants are sold in high volumes and are thus in high demand. The rest of the alien plant species in this study were sold in smaller volumes, and are therefore also in demand albeit smaller.

These five alien plants that were sold in high volumes include: *Kamal kadi*, *Brassica* sp. (mustard seeds), *C. longa* (turmeric sticks), *Cassia angustifolia*, and *T. chebula* and were sold exclusively in shops. Only two of these five species, *Brassica* sp. and *C. angustifolia*, were sold as viable propagules. These two species were found rarely occurring in the shops and no trader reported any attempts at planting these species. Therefore this indicates that if these two species 'escape' and by accident get planted that they may grow.

Reproductive alien plant parts (i.e parts that can act as propagules) were sold most frequently in this study, a phenomenon strongly believed in Indian medicine (Narasimhan *et al.*, 1999). Even though this constitutes a large proportion of alien plant species sold, only 24% of the alien propagules sold in this study were viable. Seven alien species were also found commonly in the various outlets and include: *A. calamus, G. glabra, H. isora F. vulgare, M. leucadendron, W. somnifera* and *dumapansi*. However, only two of these commonly occurring species were sold as viable propagules, namely *H. gardnerianum* and *F. vulgare*. These two species were sold in small volumes in the markets and the shops.

Twelve percent of the alien species sold in this study were invasive with five out of the six invasive species being sold as viable propagules. These viable invasive species include: *A. cordifolia, B. delagoense, H. gardnerianum, O. ficus-indica* and *R. communis* and were sold in low volumes. *Hedychium gardnerianum* was the only invasive species found commonly occurring amongst the different outlets in this study. Even though these invasive species are traded in small volumes, it is suggested that the spreading of these species through the medicinal plant trade and otherwise be monitored by the Directorate of Land Use and Soil Management of Department of Agriculture, Forestry and Fisheries.

In addition, the trade in alien plant species for *muthi* in South Africa could be viewed as a positive process. This is because the use of alien plant species has been reported to reduce the pressure on heavily harvested indigenous species (Cunningham, 1988; Williams *et al.*, 2000). Nonetheless, very little research has been conducted on this subject.

Even though the trade in alien plant species has been reported to be of limited concern, it can be suggested that 0.4 alien plant species sold in this study may become established and invasive. This was done by applying the 'tens rule' as well as looking at the percentage of imported and viable alien plant species sold in this study. Considering all analyses and facts gathered, it can be stated that the trade in alien plant species is trivial compared to the trade of indigenous plant species but that the trade in invasive alien species should be monitored.

10.2 Recommendations for future studies

Future studies should conduct similar surveys to investigate seasonal differences in the trade of alien plant species. Further work is required to identify the unidentified plants in this study. Additional insights will be gained from improved data collection of the volumes of alien plant species recorded. This should be done by specifically measuring the mass of various alien plant species that are sold. More research is needed to determine whether the use of alien plant species generally reduces the pressure on indigenous plant species and whether the trade in alien plant species increases over time. In the case of the invasive alien species traded, harvesting localities of these species can be visited and compared to the current distribution of these species. This can be done to establish whether the harvesting localities are new populations that have not yet been recorded or if these harvesting localities are hotspots.

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APPENDICES

Appendix 1. Permission granted by chairperson of Warwick and Faraday TM market to conduct the surveys.

Informed consent

Ewa Wojtasik is a Masters students from Wits University doing research on alien/exotic plants (*imithi*) used for traditional medicine. She would like to ask the traders a few questions regarding alien/exotic plants (*imithi*) and will be buying some samples (plants) from the traders.

This document is to certify that Ewa Wojtasik has asked the chairperson/head of the Herbs (Warwick) market for permission to buy samples and ask the traders a few questions.

The conditions:

- Participants understand that their names will not be asked or recorded but trader codes corresponding to purchased samples will be allocated and recorded.
- Participants do not have to answer questions if they do not want to.
- Participants can stop the students at any time and can refuse to answer any question they do not want to.
- Participants will NOT be paid for answering questions but plants will be purchased from each trader.

I (Name) MR N.DLOVU chairperson of Herbs (Warwick) market in Durban hereby grant Ewa Wojtasik permission to buy samples and ask traders a few questions regarding alien/exotic plants (*imithi*) during the period November 2010

Signature [signature] Date 03-11-2010

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Informed consent

Ewa Wojtasik would like to ask the traders a few questions regarding alien/exotic plants (*imithi*) used for traditional medicine. She is a Masters students from Wits University and will buying some samples (plants) from the traders.

This document is to certify that Ewa Wojtasik has asked the chairperson/head of the Faraday market for permission to buy samples and ask the traders a few questions.

The conditions:

- Participants understand that their names will not be asked or recorded but trader codes corresponding to purchased samples will be allocated and recorded.
- Participants do not have to answer questions if they do not want to.
- Participants can stop the students at any time and can refuse to answer any question they do not want to.
- Participants will NOT be paid for answering questions but plants will be purchased from each trader.

I (Name) SAMSON MUSA chairperson of

Faraday market in Johannesburg hereby grant Ewa Wojtasik

permission to buy samples and ask traders a few questions

regarding alien/exotic plants (*imithi*)

Signature _____ Date 31-01-17

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Appendix 2. Original list of alien plant species used for this study. The list was compiled using names of alien plant species that were cited in Ahlefeldt *et al.* (2003), as well as alien plant species that were seen sold at Faraday and Warwick traditional medicine markets prior to the initiation of the official market survey. Vernacular names as well as plant part types are listed. Plant part abbreviations: l+st=leaves and stems; bb=bulb; bk=bark; l=leaves; nt=nut; rh=rhizome; rt=root; sd=seed; sdp=seed pod; st=stem; succ st=succulent stem; tu=tuber; fr=fruit; wpl=whole plant.

Botanical name	Vernacular name	Plant part	Warwick	Faraday	Von Ahlefeldt *et al.* 2003
Acorus calamus L.	*kalamusi, ikalamuzi, indawolucwatha*	rh		✓	✓
Anacardium occidentale L.	*injumbane*	fr			✓
Anredera cordifolia (Ten.) Steenis	*madilika, indaba-ingelhlele*	tu			✓
Araucaria heterophylla (Salisb.) Franco	*abangqongozi*	bk	✓		✓
Basella sp.	*ndaba ngehlele*	tu	✓	✓	
Bryophyllum delagoense (Eckl. & Zeyh.) Schinz	*indunjane*	sdp			✓
Bryophyllum Salisb. sp.	*umvuthuza*	wpl	✓		
Cassytha filiformis L.	*iphengulula*	st			✓
Chenopodium ambrosioides L.	*unukani oyikhambi*	wpl			✓
Cinnamomum camphora (L.) J. Presl	*eroselina, uloslina*	bk		✓	
Cirsium vulgare (Savi) Ten.	*Imbune, gudl'uthukela*	wpl			✓
Coix lacryma-jobi L.	roses	sd	✓	✓	
Colocasia esculenta L. Schott	*idumbe lomfula, iphamba, indlulamithi*	rh			✓
Commelina benghalensis L.	*idangabane*	l+st	✓		
Eleutherine bulbosa (Mill.) Urb.	*abangqongqozi*	bb	✓		✓
Foeniculum vulgare Mill.	*ibeke, imbozisa*	wpl		✓	✓
Glycyrrhiza glabra L.	*lolumnandi, umlomomnandi*	rt		✓	
Hedychium J.König sp.	*impande yendawe, yebobongo*	rh	✓		✓
Helicteres isora L.	*jikantambo*	sdp		✓	
Kalanchoe pinnata (Lam.) Pers.	*umvuthuza*	wpl			✓
Macadamia F.Muell. sp.	*imbodla*	nt		✓	
Melaleuca leucadendron (L.) L.	*abaphaphi uphepha*	bk	✓		✓
Mimosa pudica L. var. *hispida* Brenan	*imbune*	wpl	✓		✓
Opuntia sp.	*dolofiya, umhlohlo isinyembane, umnwanda-nyoka*	succ-st	✓	✓	
Passiflora suberosa L.	*inhlanhla emhlophe*	wpl			✓

Botanical name	Vernacular name	Plant part	Warwick	Faraday	Von Ahlefeldt *et al.* 2003
Pedilanthus tithymaloides (L.) A.Poit. subsp. *smallii* (Millsp.) Dressler	*ibunga labesutu*	l		✓	✓
Phytolacca dioica L.	*mzimuka, mzimuka-omhlophe*	rt			✓
Ricinus communis L. var. *communis*	*umhlakuva*	sd		✓	
Sansevieria cylindrica Bojer	*uphondo-lukabhejane*	l	✓		✓
Sansevieria fasciata Cornu ex Gérôme & Labroy	*sikholokotho intelezi*	wpl	✓		
Senna sp.	*mbokoza*	sdp	✓		
Spilanthes mauritiana (Pers.) DC.	*isisilili, isisinini*	wpl	✓		✓
Withania somnifera (L.) Dunal	*munyu; munya mpondo; asghan*	rt		✓	
Unidentified	*dumanpansi, dumaphansi*	bk		✓	

Appendix 3. Questionnaires used during this study**.**

Market questionnaire

Trader information

Trader code | Block no. | Market | Date

No. of plants sold | No. of alien plants sold

Trader information

Trader code | Block no. | Market | Date

No. of plants sold | No. of alien plants sold

Trader information

Trader code | Block no. | Market | Date

No. of plants sold | No. of alien plants sold

Trader information

Trader code | Block no. | Market | Date

No. of plants sold | No. of alien plants sold

Individual plant information for traders at *muthi* market

Trader code		Alien plant no		Plant part		Quantity (unit/%)	

1. Vernacular name

1. Botanical name

2. Do you buy or harvest it or both?

Buy it		Both		Harvest	

3. Origin: Where did you buy this plant? (E.g. Town, area, province).

2. Origin: Where did you harvest this plant? (E.g. Town, area, province).

4. When did you buy this stock? (Time in weeks/ months since getting it?).

3. When did you harvest this stock? (Time in weeks/ months since getting it?).

5. How much did you buy? (E.g. No. of bags and size of bags).

4. How much did you harvest? (E.g. No. of bags and size of bags).

6. What quantity do you buy every month/year?

Month		Year	

5. What quantity do you harvest every month/year?

Month		Year	

7. How do you prepare this plant before it is used?
(☑ the correct box)

Ground	Boiled	Crushed	Scattered
☐	☐	☐	☐
Other			

6. How do you prepare this plant before it is used?
(☑ the correct box)

Ground	Boiled	Crushed	Scattered
☐	☐	☐	☐
Other			

7. Other info

***Muthi* shop questionnaire**

Trader information

Trader code | Telephone no | Date

Name & address of shop | Name of shop owner

No. of plants sold | No. of alien plants sold

Trader information

Trader code | Telephone no | Date

Name & address of shop | Name of shop owner

No. of plants sold | No. of alien plants sold

Trader information

Trader code | Telephone no | Date

Name & address of shop | Name of shop owner

No. of plants sold | No. of alien plants sold

Individual plant information

Trader code		Alien plant no		Plant part		Quantity (unit/%)	

1. Vernacular name

1. Botanical name

2. Where does the plant come from? (☑ the correct block)

India		Both/other (indicate)		South Africa	

2. Origin: Where is this plant from? (e.g. Town, area, province).

3. Origin: Where is this plant from? (e.g. Town, area, province).

3. How & THROUGH WHOM was it imported into South Africa? (via ship, plane, etc).

4. When did you harvest this stock? (Time in weeks/ months since getting it?).

5. When did you buy this stock? (Time in weeks/ months since getting it?).

5.How much did you harvest? (e.g. No. of bags and size of bags & PRICE charged).

6. How much did you buy? (e.g. Size of bags/other units & no. of bags).

6.What quantity do you harvest every month/year?

Month		Year	

7. How much does 1 unit cost? (Indicate unit of measure)

7.How do you prepare this plant before it is used? (☑ the correct box)

Boiled ☐	Crushed ☐	Scattered ☐
Other		

8. What quantity do you buy every month/year?

Month		Year	

8. &10. Substitution of alien plants: Can any indigenous plants be used for this alien plant?

9. How is this plant prepared before it is used? (√ the correct box)

Boiled ☐	Crushed ☐	Scattered ☐
Other		

Other information

Appendix 4: Inventory of alien plant species sold for traditional medicine in Johannesburg, Pretoria and Durban: 2010 survey.
The alien plant species sold in traditional medicine markets and *muthi* shops in Durban, Johannesburg and Pretoria, as recorded in this study. Botanical name, English common name (s), vernacular name (s) as cited by the traders, origin and plant part of each species is listed. Plant part abbreviations: l=leaves; st=stem; l+st=leaves and stems; bb=bulb; bk=bark; nt=nut; rh=rhizome; ga=gall; rt=root; sd=seed; sdp=seed pod; succ st=succulent stem; tu=tuber; wpl=whole plant. Plant specimens that could not be identified to genus level were recorded as unidentified. Species with an invasive status, were marked with the following symbols: * = Category 1 Declared Weed; ** = Category 2 Declared Invader (Category 2); *** = Category 3 Declared Invader (WIP, 2006). A representative specimen of each species is lodged at the Moss Herbarium of the University of Witwatersrand (J), and voucher numbers are provided. The frequency of each species is the number of times it was recorded in the study. Eight visits were made to the markets in total between October and December 2010, and 60 traders were interviewed. Visits to the *muthi* shops were conducted in October and November 2010 and January and February 2011 and 17 *muthi* shops were surveyed.

Genus	Species	Family	Common name	Vernacular Name	Plant Part	Origin	Voucher number	Frequency
Acorus	*calamus* L.	Araceae	Sweet-Flag	kalamusi; ukalamuzi; kalmoos	rh	Asia		31
Anacardium	*occidentale* L.	Anacardiaceae	Cashew	injumbane	sd	Brazil		2
Andrographis	*paniculata* (Burm. f.) Wall. ex Nees	Acanthaceae	Indian Echinacea	quinine sticks/kiryata	l+st	India		1
Anredera	*cordifolia*	Basellaceae	Madeira; Mignonette vine	ndaba nghlele; indaba-ingelhlele; umdabu	tu	Paraguay; Argentina	Wojtasik 33 (J)	8
Araucaria	*heterophylla* (Salisb.) Franco	Araucariaceae	Norfolk Island pine, Pencil pine	abangqongqozi	bk	New Zealand		4
Areca	*catechu* Willd.	Arecaceae	Betel nut	betel nut	nt	Malaysia, Philipines		2
Brassica L.	sp.	Brassicaceae		mustard seeds; pogo	sd	unknown		3
Bryophyllum	*delagoense*	Crassulaceae	Chandelier plant	umvuthuza; mvuthuza	succ-st	Madagascar	Wojtasik 20 (J)	1
Bryophyllum Salisb.	sp.	Crassulaceae		umvuthuza; mvuthuza	succ-st	unknown	Wojtasik 21 (J)	1
Bryophyllum Salisb.	sp.	Crassulaceae		umvuthuza; mvuthuza	succ-st	unknown	Wojtasik 22 (J)	1
Bryophyllum Salisb.	sp.	Crassulaceae		umvuthuza; mvuthuza	succ-st	unknown	Wojtasik 23 (J)	1
Bryophyllum Salisb.	sp.	Crassulaceae		umvuthuza; mvuthuza	succ-st	unknown	Wojtasik 24 (J)	1
Cassia	*fistula* Linn.	Fabaceae	Golden shower	mbokoza; umzuluwane; zilanyoni; liquid sticks	sdp; l	India, South-eastern Asia		3
Cassia	*angustifolia* Vahl	Fabaceae	Senna	senna pods; senna leaves	sdp; l	unknown		9
Cinnamomum	*camphora* (L.) J. Presl.*	Lauraceae	Camphor tree	uroselina; uroslina; roslina; uloslina	bk	Malaysia; Japan		7
Cinnamomum L.	sp.	Lauraceae		cinnamon sticks	bk	India, Sri Lanka		3
Coix	*lacryma-jobi* L.	Poaceae	Job's tears	roses; cwabesi; imfibinga; teething beads; tandkraal	sd	Tropics		9
Commelina	*benghalensis* L.	Commelinaceae	Benghal commelina	indangabane	l+st	Tropical Africa, Asia	Wojtasik 30 (J)	1
Coriandrum	*sativum* L.	Apiaceae	Coriander	coriander seeds; dhania	sd	Southern Europe, Southwestern Asia		2
Curcuma	*longa* Linn	Zingiberaceae	Tumeric	turmeric sticks; vuka	rt	unknown		5
Eleutherine	*bulbosa* (Mill.) Urb.	Iridaceae		abangqongqozi; abangqongqozi iqhude	bb	Cuba, Brazil		4
Foeniculum	*vulgare* Mill.	Apiaceae	Fennel	imboziso; singala salgazi; fennel; ibeke; jeera; shinga	l+st; sd	Europe	Wojtasik 36 (J)	12
Glycyrrhiza	*glabra* L.	Fabaceae	Liquorice	umlolumnandi; mlomonandi; sweet roots	rt	Southern Europe, Southwestern Asia		20
Hedychium	*gardnerianum* Ker Gawl.*	Zingiberaceae	kahili ginger; wild ginger	impande yendawe yebobongo; indawe igobongo; ibunga labesutu; ginger	rh	unknown	Wojtasik 37 (J)	11
Helicteres	*isora* L.	Malvaceae	Kaivum	jikantambo; jigantambu; unfandaqutaile	sd	Tropical Asia		21
Macadamia F.Muell.	sp.	Proteaceae	Macadamia nut	imbodla	nt	Eastern Australia		1
Melaleuca	*leucadendron* (L.) L.	Myrtaceae	Long-leaved paperbark	abaphaphi uphepha	bk	Australia, Malaysia	Wojtasik 31 (J)	12
Mimosa	*pudica* L. var. *hispida* Brenan	Fabaceae	Sensitive plant	imbune	l+st	Brazil	Wojtasik 34 (J)	1
Opuntia	*robusta* H.L.Wendl. in Pfeiff.	Cactaceae		dolifiya; umhlohlo	succ-st	Mexico	Wojtasik 27, 29 (J)	6
Opuntia	*ficus-indica* (L.) Mill.*	Cactaceae	Sweet prickly pear	dolifiya	succ-st	Mexico	Wojtasik 28 (J)	8

Genus	Species	Family	Common name	Vernacular Name	Plant Part	Origin	Voucher number	Frequency
Pedilanthus	*tithymaloides* (L.) A.Poit. subsp. *smallii* (Millsp.) Dressler	Euphorbiaceae	Bird cactus	ibunga labesutu; ingongomazemikhontho, isidletshana	succ-st	South America, West Indies	Wojtasik 35 (J)	5
Platycarpha Less.	sp.	Asteraceae		imbune	wpl	unknown		1
Quercus	*infectoria* Olivier	Fagaceae	Aleppo oak	manjupal; mthuma	ga	Eastern Mediterannean, Iran		2
Ricinus	*communis* L. var. *communis***	Euphorbiaceae	Castor-oil bean	umhlakuva	sd	Tropical Africa		6
Sansevieria	*cylindrica* Bojer	Dracaenaceae	Elephant's toothpick	uphondo lukebhejane intelezi	succ-st	Tropical Africa	Wojtasik 25 (J)	3
Sansevieria	*fasciata* Cornu ex Gérôme & Labroy	Dracaenaceae		sikholokotho intelezi	succ-st	unknown	Wojtasik 26 (J)	1
Senna Mill.	sp.	Fabaceae		mbokoza	sdp	unknown		1
Spilanthes	*mauritiana* (Pers.) DC.	Asteraceae	Electric plant	sinini	l+st	unknown	Wojtasik 32 (J)	5
Terminalia	*chebula* Retz.	Combretaceae	Arulu, Kaddukay	hurle (large)	sd	India, Burma		2
Terminalia	*chebula* Retz.	Combretaceae	Arulu, Kaddukay	hurle (small)	sd	India, Burma		2
Withania	*somnifera* (L.) Dunal	Solanaceae	Winter cherry; Indian ginseng	munyu; umunyu; muyu; munya mpondo; asghan	rt	Africa, Southeastern Europe and Asia		14
uniden. 1				avalkadle	sdp	unknown		1
uniden. 2				dumapansi	bk	unknown		10
uniden. 3				girmalasing	sdp	unknown		2
uniden. 4				ibande	bk	unknown		1
uniden. 5				inderjow	sd	unknown		2
uniden. 6				indian pearls; indian peanuts; indian beans; indian nut; jamal gota	sd	unknown		5
uniden. 7				inhlanhla emhlophe	st	unknown		6
uniden. 8				iphengula	rh	unknown		3
uniden. 9				kachka	sd	unknown		1
uniden. 10				kamal kadi; kamal kachie; impitie	sd	unknown		3
uniden. 11				kapoor kachi	tu	unknown		1
uniden. 12				unukani oyikhambi	bk	unknown		5
							Total:	273

Appendix 5: Inventory of alien plant species used and sold for traditional medicine in South Africa: compiled from 41 studies published from 1895 to 2011.
List of alien plant species used for traditional medicine in South Africa in the years 1895-2011, collated from in 41 studies. Botanical name; common name (s); source citing origin of particular species '**'; origin; continent to which the origin of the particular species belongs and 's' or 'u' referring to whether the species was sold or used for traditional medicine. References to the sources that cited the origins as well as the references that cited a particular alien plant species being used and/sold are at the end of the table. Abbreviations for the languages of common names include: E: English; Afr: Afrikaans; Z: Zulu and I-Indian. All genera and species in bold indicate species identified from this study, reference number 40, which is the study conducted in 2011 in Durban and Johannesburg muthi shops (MS) and markets (Warwick and Faraday), as well as Pretoria MS. References marked with '*' refer to studies that cited alien plant species as unidentified, however through this study, these unidentified species were identified to botanical name.

Family name	Genus	Species	Common name (s)	** Origin	Continent	Sold (s) / Used (u)	Reference#
Acanthaceae	*Acanthus*	*pubescens* (Thomson ex Oliv)	Spiney Acanthus (E)	[13] Tropical Africa	Africa	u	3
Acanthaceae	***Andrographis***	***paniculata* (Burm. f.) Wall. ex Nees**	Indian echinacea (E)	unknown	unknown	s & u	40
Agavaceae	*Agave*	*americana* subsp. *americana* var. *americana*	Century plant; Maguey (E)	[13] Mexico	North America	u	18
Agavaceae	*Agave*	*sisalana* Perrine	Sisal (E); Garingboom (Afr)	[13] Mexico	North America	s & u	8
Agavaceae	*Agave* L.	sp.	unknown	unknown	unknown	u	14
Amaranthaceae	*Achyranthes*	*aspera* L. var. *aspera*	Burweed (E)	[9] New Zealand	Australia	u	3, 18
Amaranthaceae	*Alternanthera*	*sessilis* (L.) DC.	unknown	[13] Pantropical regions	Africa; Asia; Australia	u	3
Amaranthaceae	*Amaranthus*	*caudatus* L.	Love-lies-bleeding (E)	[13] South America	South America	u	30
Amaranthaceae	*Amaranthus*	*hybridus* L. subsp. *cruentus* (L.) Thell.	Prince's feather (E)	[13] Eastern USA-South America	N & S America	u	19
Amaranthaceae	*Amaranthus*	*spinosus* L.	Prickly calalue; Thorny amaranth (E)	[16] North America	North America	u	3
Amaranthaceae	*Gomphrena*	*celosioides* Mart.	Batchelor's button (E)	[36] Paraguay	South America	u	3
Amaranthaceae	*Gomphrena*	*globosa* L.	Globe amaranth (E)	[13] India	Asia	u	3
Amaryllidaceae	*Allium*	*cepa* L.	Onion (E)	[13] Afghanistan	Asia	u	33
Amaryllidaceae	*Allium*	*sativum* L.	Garlic (E)	[13] Asia	Asia	u	33
Anacardiaceae	***Anacardium***	***occidentale* L.**	Cashew (E)	[13] Central America	North America	s & u	3, 40
Anacardiaceae	*Mangifera*	*indica* L.	Mango (E)	[13] Burma	Asia	u	3
Annonaceae	*Annona*	*reticulata* L.	Bullock's heart (E)	[13] Florida-Peru; West Indies	N & S America; Asia	s & u	8
Apiaceae	*Anethum*	*graveolens* L.	Dill (E)	[13] Europe; Southwest Asia	Europe; Asia	u	14
Apiaceae	*Anthriscus*	*sylvestris* var. *sylvestris* (L.) Hoffm.	Cow parsley (E)	[11] Europe; Western Asia	Europe; Asia	u	3
Apiaceae	*Apium*	*graveolens* L.	Celery (E)	[13] Europe	Europe	u	3
Apiaceae	*Centella*	*asiatica* (L.) Urb.	Pennywort (E)	[34] Mexico	North America	u	8, 18, 32
Apiaceae	***Coriandrum***	***sativum* L.**	Coriander (E)	[13] Southern Europe-Southwest Asia	unknown	s & u	40
Apiaceae	*Daucus*	*carota* L.	Carrot (E)	[13] Europe-Asia	Europe; Asia	u	3
Apiaceae	***Foeniculum***	***vulgare* Mill.**	Fennel (E)	[13] Europe	Europe	s & u	3, 8, 14, 18, 29, 31, 35,
Apiaceae	*Petroselinum*	*crispum* (Mill.) A.W.Hill	Pietersielie (E)	[13] Europe	Europe	u	3, 33
Apocynaceae	*Araujia*	*sericifera* Brot.	Moth-Catcher; Cruel plant (E)	[13] Brazil	South America	u	9
Apocynaceae	*Catharanthus*	*roseus* (L.) G.Don	Madagascar periwinkle (E)	[13] Madagascar	Africa	u	3, 9, 15, 31
Apocynaceae	*Nerium*	*oleander* L.	Ceylon rose (E); Selonroos (Afr)	[13] Morocco-China	Africa; Asia	s & u	8
Apocynaceae	*Vinca*	*major* L.	Greater periwinkle (E)	[13] Europe	Europe	u	3
Apocynaceae	*Gomphocarpus*	*fruticosus* E. Mey.	Milkweed (E)	unknown	unknown	u	18
Araceae	***Acorus***	***calamus* L.**	Sweet-Flag (E.); Makkalmoes (Afr.)	[13] Garden origin	Asia	s & u	3, 8, 14, 15, 26, 30, 31, 37, 40
Araceae	*Colocasia*	*esculenta* (L.) Schott	Elephant's ear; Taro; Amandumbe (E)	[13] Tropical East Africa	Africa	s & u	35
Araceae	*Colocasia*	*antiquorum* var. *esculenta*	Dasheen; Taro (E)	[20] East Indies	Asia	u	14, 15
Araucariaceae	*Araucaria*	*bidwillii* Hook.	Bunya-Bunya (E)	[13] Australia	Australia	u	9
Araucariaceae	***Araucaria***	***heterophylla* (Salisb.) Franco**	Norfolk Island pine; Pencil pine (E)	[13] New Zealand	Australia	s & u	40
Arecaceae	***Areca***	***catechu* Willd.**	Betel nut (E)	[13] Malaysia; Philipines	Asia	s & u	40
Asphodeleceae	*Ageratum*	*conyzoides* L.	Invading ageratum (E)	[20] Tropics	N & S America; Africa; Asia; Australia	u	18
Asteraceae	*Acanthospermum*	*australe* (Loefl.) Kuntze	Australian starbur; Brazilian starbur; Creeping starbur (E)	[19] America	N & S America	u	3

Family name	Genus	Species	Common name (s)	** Origin	Continent	Sold (s) / Used (u)	Reference#
Asteraceae	*Acanthospermum*	*glabratum* (DC.) Wild	Creeping starbur; Five-Seeded prostrate starbur; Prostrate starbur; Sheepbur (E)	[2] Tropical America	N & S America	u	41
Asteraceae	*Acanthospermum*	*hispidum* DC.	Bristly starbur (E); Donkieklits (Afr)	[3] Tropical America	N & S America	s & u	3, 8, 39
Asteraceae	*Achillea*	*millefolium* L. sens. lat.	Milfoil (E)	[13] Europe-Western Asia	Europe; Asia	u	3
Asteraceae	*Anthemis*	*cotula* L.	Mayweed; Stinking chamomile (E)	[13] Europe-Arabia	Europe; Asia	u	3
Asteraceae	*Artemisia*	*absinthium* L.	Absinthe; Wormwood (E)	[13] Europe	Europe	u	33
Asteraceae	*Bidens*	*bipinnata* L.	Black-jack (E); Black fellows; Beggar tick (E)	[8] India	Asia	u	3
Asteraceae	*Bidens*	*pilosa* L.	Black-jack (E)	[1] Tropics	N & S America; Africa; Asia; Australia	u	3, 9, 15, 18, 27
Asteraceae	*Carduus*	*tenuiflorus* Curtis	Corsican thistle (E)	[11] Europe; Asia; North America	North America; Europe; Asia	u	9
Asteraceae	*Carthamus*	*lanatus* L.	Distaff Thistle; Woolly Safflower (E)	[20] Europe	Europe	u	3
Asteraceae	*Centaurea*	*calcitrapa* L.	Star thistle (E)	[16] Europe; North Africa; Temperate Asia	Africa; Europe; Asia	u	3
Asteraceae	*Centaurea*	*cyanus* L.	Cornflower; Bachelor's buttons (E)	[13] Eurasia	Europe; Asia	u	3
Asteraceae	*Centaurea*	*melitensis* L.	Cockspur; Maltese thistle; Saucy jack (E)	[13] Southern Europe	Europe	u	3
Asteraceae	*Centaurea*	*solstitialis* L.	Burweed (E)	[40] Sweden	Europe	u	3
Asteraceae	*Chrysanthemum*	*segetum* L.	unknown	[15] Europe	Europe	u	3
Asteraceae	*Cichorium*	*intybus* L. subsp. *intybus*	Chicory (E); Sigorei (Afr)	[13] Mediterannean region	Africa; Europe; Asia	u	3, 31
Asteraceae	*Cirsium*	*arvense* (L.) Scop.	Canada thistle; Creeping thistle; Field thistle (E)	unknown	unknown	u	3
Asteraceae	*Cirsium*	*vulgare* (Savi) Ten.	Scotch thistle (E)	[11] Europe	Europe	s & u	3, 35
Asteraceae	*Cnicus*	*benedictus* L.	Karmedik (E)	[13] Mediterannean region	Africa; Europe; Asia	u	30, 33
Asteraceae	*Conyza*	*canadensis* (L.) Cronquist	Fleabane (E); Horseweed (E); Armoedskruid (Afr); skraalhans (Afr)	[3] Eastern North America	North America	u	3
Asteraceae	*Conyza*	*sumatrensis* (Retz.) E.Walker var. *sumatrensis*	Tall Fleabane (E)	unknown	unknown	u	18
Asteraceae	*Cosmos*	*bipinnatus* Cav.	Bug weed (E); Grootbitterappel (Afr)	[11] America	unknown	u	3
Asteraceae	*Eclipta*	*prostrata* (L.) L.	Eclipta (E)	[38] Peru	South America	s & u	3, 8, 14, 37
Asteraceae	*Ethulia*	*conyzoides* L.f. subsp.	Blue weed (E)	unknown	unknown	u	6
Asteraceae	*Galinsoga*	*parviflora* Cav.	Galinsoga weed; Gallant soldier; Small-flowered quickweed (E)	[3] S America	South America	u	3
Asteraceae	*Helianthus*	*annuus* L.	Common sunflower (E)	[13] Canada-Mexico	North America	u	3
Asteraceae	*Lactuca*	*serriola* L.	Prickly lettuce (E)	[13] Europe	Europe	u	3
Asteraceae	*Leucanthemum*	*vulgare* Lam.	Ox-eye daisy (E)	[13] Europe	Europe	u	3
Asteraceae	*Picris*	*echioides* L.	Ox-tongue (E)	[16] Europe; North Africa	Africa; Europe	u	3
Asteraceae	***Platycarpha* Less.**	**sp.**	unknown	unknown	unknown	s & u	40
Asteraceae	*Senecio*	*vulgaris* L.	Groundsel (E)	[13] N & S America; Africa; Europe; Asia; Australia	N & S America; Africa; Europe; Asia; Australia	u	3
Asteraceae	*Sigesbeckia*	*orientalis* L.	Common St. Paul's wort; Indian weed; Saint paul's herb (E)	unknown	Africa; Europe; Asia	u	3
Asteraceae	*Silybum*	*marianum* (L.) Gaertn.	Holy or milk thistle (E)	[13] Africa; Europe; Asia	Africa; Europe; Asia	u	3
Asteraceae	*Sonchus*	*oleraceus* L.	Smooth sow-thistle (E)	[13] Europe; Asia	Europe; Asia	u	3
Asteraceae	***Spilanthes* *mauritiana* (Pers.) DC.**		Electric plant (E)	unknown	unknown	s & u	18, 35, 40
Asteraceae	*Tagetes*	*minuta* L.	Taal khaki bush; Lang kakiebos (Afr)	[11] South America	Africa; Asia	u	30
Asteraceae	*Taraxacum*	*officinale* Weber sensu lato	Dandelion (E)	[13] Europe; Asia	Africa; Asia	u	3
Asteraceae	*Tithonia*	*diversifolia* (Hemsl.) A.Gray	Mexican sunflower (E)	[13] North America	North America	u	3
Asteraceae	*Tragopogon*	*porrifolius* L.	Salsify (E)	[13] Europe	Europe	u	3
Asteraceae	*Tridax*	*procumbens* L.	Daisy (E)	[11] N & S America	N & S America	u	18
Asteraceae	*Xanthium*	*spinosum* L.	Winter cherry (E)	[24] unknown	unknown	u	3
Asteraceae	*Xanthium*	*strumarium* L.	Bur weed (E)	[41] United States	Cosmopolitan distribution?	u	3
Balsaminaceae	*Impatiens*	*walleriana* Hook.f.	Busy lizzie (E)	[13] Tropical Africa	Africa	u	3
Basellaceae	***Anredera* *cordifolia* (Ten.) Steenis**		unknown	unknown	unknown	s & u	9, 40

Family name	Genus	Species	Common name (s)	** Origin	Continent	Sold (s) / Used (u)	Reference#
Boraginaceae	*Buglossoides*	*arvenis* (L.) I.M.Johnst.	Bastard alkanet; Field gromwell (E)	[13] Europe	unknown	u	3
Brassicaceae	*Brassica*	*juncea* (L.) Czern. & Coss.	Indian mustard (E)	[13] Central and Eastern Asia	Asia	u	3
Brassicaceae	*Brassica*	*nigra* (L.) W.D.J.Koch	Black mustard (E)	[13] Europe-Western Asia	Europe; Asia	u	3
Brassicaceae	*Brassica*	*rapa* L.	Turnip; Sarson; Pak-Choi (E)	[13] Europe-Western Asia	Europe; Asia	u	3
Brassicaceae	***Brassica* L.**	**sp.**	unknown	unknown	unknown	s & u	40
Brassicaceae	*Capsella*	*bursa-pastoris* (L.) Medik.	Shepherd's purse (E)	[13] Europe	Europe	u	3
Brassicaceae	*Nasturtium*	*officinale* R.Br.	Watercress (E)	[13] Europe and Northern Asia	Europe, Asia	u	3
Brassicaceae	*Raphanus*	*raphanistrum* L.	Jointed or White charlock (E)	[11] Europe; Asia	Europe; Asia	u	3
Brassicaceae	*Raphanus*	*sativus* L.	Radish (E)	[13] Temperate Asia	Asia	u	3
Brassicaceae	*Sinapis*	*alba* L.	White mustard (E)	[13] Europe	Europe	u	3
Bromeliaceae	*Tillandsia*	*fasciculata* Sw.	unknown	[13] N & S America	N & S America	u	9
Cactaceae	*Cereus*	*peruvianus* (L.) Mill.	Apple cactus (E); Bobbejaanpaal (Afr)	[11] South America	South America	s & u	8
Cactaceae	***Opuntia* *ficus-indica* (L.) Mill.**		Sweet prickly pear (E)	[13] Mexico	North America	s & u	3, 13, 40
Cactaceae	***Opuntia* *robusta* H.L.Wendl. in Pfeiff.**		unknown	[13] Mexico	North America	s & u	40
Cactaceae	*Opuntia*	*monacantha* (Willd.) Haw.	Sour prickly pear (E)	[44] south-eastern South America	South America	u	3, 21
Cactaceae	*Opuntia* Mill.	sp.	Prickly pear (E)	unknown	unknown	s & u	11
Cactaceae	*Schlumbergera*	*truncata* (Haw.) Moran	unknown	[21] South America	South America	s & u	8
Cannabaceae	*Cannabis*	*sativa* var. *indica* L.	Dagga; Marijuana; Hemp (E)	[13] Central Asia	Asia	u	7, 9, 14, 16, 30, 33
Caricaceae	*Carica*	*popaya* L.	Pawpaw; Papaya (E)	[13] Tropical America	N & S America	u	21
Caryophyllaceae	*Polycarpaea*	*corymbosa* (L.) Lam. var. *corymbosa*	unknown	unknown	unknown	u	3
Caryophyllaceae	*Spergula*	*arvensis* L.	Corn spurry; Toadflax (E)	[16] Europe	Europe	u	3
Caryophyllaceae	*Stellaria*	*media* (L.) Vill.	Chickweed; Starwort; Stitchwort (E)	[16] North America; Europe; Asia	North America; Europe; Asia	u	3
Casuarinaceae	*Casuarina*	*equisetifolia* L.	Horsetail tree (E)	[13] Indomalesia	Asia	u	3
Chenopodiaceae	*Atriplex*	*nummularia* Lindl.	Old man's saltbush (E)	[13] Australia	Australia	u	32
Chenopodiaceae	*Beta*	*vulgaris* L. subsp. *vulgaris*	Beetroot (E)	[13] Mediterannean region	Africa; Europe; Asia	u	3
Chenopodiaceae	*Chenopodium*	*album* L.	Goosefoot; Fat hen (E)	[13] Cosmopolitan distribution	Cosmopolitan distribution?	u	4, 11, 15
Chenopodiaceae	*Chenopodium*	*ambrosioides* L.	Wormseed (E)	[13] South America	South America	s & u	3, 11, 15, 37
Chenopodiaceae	*Chenopodium*	*opulifolium* var.	Broad-leaved goosefoot (E)	[28] Belgium	Europe	u	3
Chenopodiaceae	*Chenopodium*	*schraderianum* Roem. Schult.	Schrader goosefoot; Schrader's spinach (E)	unknown	unknown	u	3
Combretaceae	***Terminalia* *chebula* Retz.**		Aralu; Kaddukay (E)	[13] Asia	Asia	s & u	40
Commelinaceae	***Commelina* *benghalensis* L.**		Benghal Commelina (E)	[30] Tropical Africa; Asia	Africa	s & u	11, 30, 40
Convolvulaceae	*Convolvulus*	*arvensis* L.	Field bindweed (E); Wild morning-glory (E); Akkerwinde (Afr); Klimop (Afr)	[18] Europe, Asia	Europe; Asia	u	3
Convolvulaceae	*Cuscuta*	*epithymum* Murray	Clover dodder; Flax dodder; Lesser dodder; Dodder (E)	[35] Morocco	Africa	u	3
Convolvulaceae	*Ipomoea*	*alba* L.	Moonflower (E)	[13] USA-Argentina	N & S America	s & u	8
Convolvulaceae	*Ipomoea*	*batatas* (L.) Lam.	Sweet potato (E)	[13] USA-Argentina	N & S America	u	3
Convolvulaceae	*Ipomoea*	*indica* (Burm.f.) Merr.	unknown	unknown	unknown	u	14
Convolvulaceae	*Ipomoea*	*purpurea* (L.) Roth	Common morning-glory (E)	[13] USA-Argentina	N & S America	u	3, 14
Crassulaceae	***Bryophyllum* *delagoense* (Eckl. & Zeyh.) Schinz**		Chandelier plant (E)	[13] Madagascar	Africa	s & u	8, 40
Crassulaceae	***Bryophyllum* Salisb.**	**sp.**	unknown	unknown	unknown	s & u	40
Crassulaceae	*Kalanchoe*	*pinnata* (Lam.) Pers.	Air plant (E)	[13] Madagascar	Africa	s & u	35
Cucurbitaceae	*Momordica*	*charantia* L.	Bitter cucumber; Leprosy gourd (E)	[13] Pantropical regions	Africa; Asia; Australia	u	3
Cupressaceae	*Cupressus* L.	sp.	unknown	unknown	unknown	s & u	8, 12, 37
Cyperaceae	*Cyperus*	*esculentus* L.	Yellow nut sedge (E)	[20] North America; Europe; Asia	North America; Europe; Asia	u	11, 18
Dennstaedtiaceae	*Pteridium*	*aquilinum* subsp. *aquilinum* (L.) Khum	Bracken; Eagle fern (E)	[11] Cosmopolitan distribution	Cosmopolitan distribution?	u	15, 27
Dracaenaceae	***Sansevieria* *cylindrica* Bojer**		Elephant's toothpick (E)	[20] Africa	Africa	s & u	40
Dracaenaceae	***Sansevieria* *fasciata* Cornu ex Gérôme & Labroy**		unknown	unknown	unknown	s & u	40

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Dracaenaceae	*Schinus*	*molle* L.	Pepper tree (E)	[13] N & S America	N & S America	u	3, 9
Euphorbiaceae	*Euphorbia*	*helioscopia* L.	Cat's milk; Milkweed; Sun euphorbia; Spurge (E)	[31] France	Europe	u	18
Euphorbiaceae	*Euphorbia*	*heterophylla* L.	Mexican fire plant (E)	[11] Florida; Texas; Tropical America	N & S America	u	3
Euphorbiaceae	*Euphorbia*	*indica* Lam.	unknown	[7] India	Asia	u	3
Euphorbiaceae	*Euphorbia*	*lathyris* L.	Caper spurge (E)	[20] Europe	Europe	u	3
Euphorbiaceae	*Euphorbia*	*peplus* L.	Spurge; Milkweed; Petty spurge (E)	[13] Europe-Western Asia	Europe; Asia	u	3
Euphorbiaceae	*Euphorbia*	*prostrata* (Aiton) Small	unknown	[42] United States	North America	u	3
Euphorbiaceae	*Jatropha*	*curcas* L.	Purging nut (E); Purgeerboontjie (Afr)	[13] Mexico-South America	N & S America	u	7, 11, 21, 31
Euphorbiaceae	*Jatropha*	*podagrica* Hook.	unknown	[13] Guatamala, Panama	North America	s & u	11
Euphorbiaceae	*Manihot*	*esculenta* Crantz	Bitter or Sweet cassava; Manioc; Tapioca (E)	[13] South America	South America	u	3
Euphorbiaceae	*Mercurialis*	*annua* L.	Annual mercury (E)	[13] Europe	Europe	u	3
Euphorbiaceae	***Pedilanthus***	***tithymaloides* (L.) A.Poit. subsp. *smallii* (Millsp.) Dressler**	Bird cactus (E)	[13] South America; West Indies	N & S America	s & u	8, 40
Euphorbiaceae	***Ricinus***	***communis* L. var. *communis***	Castor oil bean (E)	[13] Tropical Africa	Africa	s & u	3, 7, 9, 13, 15, 18, 21, 33, 40
Euphorbiaceae	*Vernicia*	*fordii* (Hemsl.) Airy Shaw	Tung tree (E)	[13] Asia	Asia	u	3
Fabaceae	*Acacia*	*decurrens* (Wendl.) Willd.	Green wattle (E)	[13] Eastern Australia	Australia	u	3
Fabaceae	*Acacia*	*farnesiana* (L.) Willd.	Cassie; Opopanax (E)	[13] Central America	North America	u	3
Fabaceae	*Acacia*	*melanoxylon* R.Br.	Australian blackwood (E)	[13] Eastern Australia	Australia	u	30
Fabaceae	*Acacia*	*pycnantha* Benth.	Golden wattle (E)	[13] Australia	Australia	u	3
Fabaceae	*Albizia*	*lebbeck* (L.) Benth.	Lebbeck tree; Siris (E)	[13] India-Australia	Asia; Australia	u	3
Fabaceae	*Arachis*	*hypogaea* L.	Peanut; Groundnut; Monkeynut (E)	[13] Brazil	South America	u	3
Fabaceae	*Bauhinia*	*variegata* L.	Orchid tree (E)	[13] India-China	Asia	u	3
Fabaceae	*Caesalpinia*	*gilliesii* (Wall. ex Hook.) Benth.	Mal De Ojo (E)	[13] Argentina; Uraguay	Cosmopolitan tropics	u	3
Fabaceae	*Caesalpinia*	*pulcherrima* (L.) Sw.	Barbados pride; Peacock flower (E)	[13] West Indies	Cosmopolitan tropics	u	3
Fabaceae	***Cassia***	***angustifolia* Vahl**	Senna (E)	unknown	unknown	s & u	40
Fabaceae	***Cassia***	***fistula* Linn.**	Golden shower (E)	[13] India-Southeast Asia	Asia	s & u	40
Fabaceae	*Ceratonia*	*siliqua* L.	Carob (E)	[13] Mediterannean region	Africa; Europe; Asia	u	3
Fabaceae	*Crotalaria*	*brevidens* var. *intermedia* (Kotschy) Polhill	unknown	[13] Tropical Africa	unknown	u	3
Fabaceae	*Crotalaria*	*juncea* L.	Bombay; Sunn hemp (E)	[5] India	unknown	u	3
Fabaceae	*Cytisus*	*scoparius* L.	Common broom (E)	[13] Europe	Europe	u	3
Fabaceae	*Gleditsia*	*triacanthos* L.	Honey locust (E)	[13] Eastern USA	North America	u	3
Fabaceae	***Glycyrrhiza***	***glabra* L.**	Liquorice (E)	[13] Southern Europe-Southwest Asia	Europe; Asia	s & u	7, 20, 32, 40
Fabaceae	*Lablab*	*purpureus* subsp.	Lablab; Hyacinth bean; Bonavist (E)	[13] Pantropical regions	Africa; Asia; Australia	u	3
Fabaceae	*Lablab*	*purpureus* subsp. *purpureus*	Lablab; Hyacinth bean; Bonavist (E)	[13] Pantropical regions	Africa; Asia; Australia	u	3
Fabaceae	*Lantana*	*camara* L.	Lantana (E)	[18] Central & South America	North & South America	u	3, 9, 21
Fabaceae	*Melilotus*	*indica* (L.) All.	Small melilot (E)	[13] Canary Island-India	Africa; Asia	u	3
Fabaceae	*Melilotus*	*officinalis* (L.) Pall	Yellow or Ribbed melilot (E)	[13] Eurasia	Europe; Asia	u	3
Fabaceae	*Mimosa*	*pigra* L.	Sensitive plant (E)	[13] Tropical Africa; America	N & S America; Africa	s & u	7, 26, 39
Fabaceae	***Mimosa***	***pudica* L. var. *hispida***	Sensitive plant (E)	[13] Brazil	South America	s & u	3, 8, 35, 40
Fabaceae	*Paraserianthes*	*lophantha* (Willd.) I.C.Nielsen subsp. *lophantha*	Stink bean (E)	[13] Western Australia	Australia	u	3
Fabaceae	*Parkinsonia*	*aculeata* L.	Jerusalem thorn; Ratama (E)	[13] Southern USA; Mexico	North America	u	3
Fabaceae	*Robinia*	*pseudoacacia* L.	Black locust (E)	[13] Eastern USA	North America	u	3
Fabaceae	*Senna*	*didymobotrya* (Fresen.) H.S.Irwin & Barneby	Chemagro; Oatmeal cassia (E)	[13] Tropical Africa	Africa	s & u	
Fabaceae	*Senna*	*occidentalis* (L.) Link	Stinking weed; Coffee senna (E)	[13] Africa; Asia; Australia	Africa; Asia; Australia	u	14
Fabaceae	*Senna*	*septemtrionalis* (Vivienne.) Irwin & Barneby	Arsenic bush; Dooley weed (E)	[13] Mexico-Peru	N & S America	u	14
Fabaceae	***Senna* Mill.**	**sp.**	unknown	unknown	unknown	s & u	40
Fabaceae	*Styphnolobium*	*japonicum* (L.) Schott	unknown	unknown	South America	u	3

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Fabaceae	*Tamarindus*	*indica* L.	Tamarind (E)	[13] Africa; Asia	Europe; Asia	u	3
Fabaceae	*Tephrosia*	*densiflora* Hook. f.	unknown	unknown	Asia	u	14
Fabaceae	*Tephrosia*	*purpurea* subsp. *purpurea*	Wild indigo; Ash vetch (E)	[13] Africa; Asia	Africa; Asia	u	3
Fabaceae	*Trifolium*	*pratense* var. *pratense*	Red or Purple clover (E)	[13] Europe	Europe	u	3
Fagaceae	***Quercus***	***infectoria* Olivier**	Aleppo oak (E)	[13] Eastern Mediterannean region-Iran	Europe; Asia	s & u	40
Fagaceae	*Quercus*	*robur* L.	English oak (E)	[13] Europe; Southwest Asia	Europe; Asia	u	3
Fumariaceae	*Fumaria*	*muralis* subsp. *muralis*	Pink weed; Fumitory (E)	[39] Spain	Europe	u	3
Geraniaceae	*Erodium*	*cicutarium* (L.) L'Hér.	Common storksbill (E)	[13] Europe	Europe	u	3
Hypericaceae	*Hypericum*	*perforatum* L.	Saint John's wort (E); Johanneskruid (Afr)	[13] Europe-China	Europe; Asia	u	3, 31
Iridaceae	*Belamcanda* Adans.	sp.	unknown	unknown	unknown	u	14
Iridaceae	***Eleutherine***	***bulbosa* (Mill.) Urb.**	unknown	[13] Cuba-Brazil	N & S America	s & u	7, 14, 40
Iridaceae	*Iris*	*domestica* (L.) Goldblatt & Mabb.	unknown	unknown	unknown	u	14
Lamiaceae	*Hyptis*	*pectinata* (L.) Poit.	unknown	[5] Tropical America	N & S America	u	3
Lamiaceae	*Marrubium*	*vulgare* L.	White horehound (E)	[13] Eurasia	Europe; Asia	u	10
Lamiaceae	*Mentha*	*spicata* L.	Kruisement (E)	[13] Garden origin	Garden origin ?	u	3, 33
Lamiaceae	*Plectranthus*	*barbatus* Andrews.	unknown	[13] India	Asia	u	3
Lamiaceae	*Prunella*	*vulgaris* L.	Self-heal; Heal-all (E)	[11] North America	North America	u	3
Lamiaceae	*Rosmarinus*	*officinalis* var. L.	Rosemary (E)	[13] Mediterannean region	Africa; Europe; Asia	u	32
Lamiaceae	*Salvia*	*coccinea* Etl.	Red salvia (E)	[13] South America	South America	u	3
Lamiaceae	*Salvia*	*officinalis* L.	Sage (E); Salie; Maksalie (Afr)	[13] Europe	Europe	u	33
Lauraceae	*Cassytha*	*filiformis* L.	False dodder (E)	[13] Cosmopolitan tropics	Cosmopolitan tropics	s & u	21, 35
Lauraceae	***Cinnamomum***	***camphora* (L.) J. Presl.**	Camphor tree (E)	[13] Malaysia; Japan	Asia	s & u	5, 8, 12, 22, 26, 31, 37,
Lauraceae	*Cinnamomum*	*zeylanicum* Nees.	Cinnamon (E)	Indonesia	Asia	s & u	8, 14, 39
Lauraceae	***Cinnamomum* L.**	**sp.**	unknown	unknown	unknown	s & u	40
Malvaceae	***Helicteres***	***isora* L.**	Kaivum (E)	[13] Tropical Asia	Asia	s & u	7*, 40
Malvaceae	*Malva*	*pusilla* Sm.	low mallow	unknown	unknown	u	3
Malvaceae	*Malva*	*verticillata* var. *verticillata*	Curled mallow (E)	[13] Northern Temperate regions	North America; Europe; Asia	s & u	37
Malvaceae	*Malva*	*parviflora* var. *parviflora*	Brood-en-botter (Afr); Kasies (Afr)	[12] Europe; Asia	Europe; Asia	s & u	1, 9, 25, 37
Martyniaceae	*Proboscidea*	*louisianica* (Mill.) Thell. subsp. *fragrans* (Lindl.)	Unicorn plant (E)	[21] Southwest USA	North America	s & u	3, 39
Martyniaceae	*Proboscidea*	*louisianica* (Mill.) Thell.	unknown	[11] Mexico	North America	u	3
Meliaceae	*Melia*	*azedarach* L.	Syringa (E)	[18] Asia to Australia	Asia; Australia	u	3, 14
Menispermaceae	*Cocculus*	*hirsutus* (L.) Diels	Bushveld moonseed creeper (E)	unknown	unknown	u	3
Moench	*Schkuhria*	*pinnata* (Lam.) Cabrera	Dwarf marigold; Khaki bush (E)	[27] South America	South America	u	3, 30
Musaceae	*Musa*	*paradisiaca* L.	Plantain (E)	[20] Tropical Asia	Asia	u	21
Myrtaceae	*Eucalyptus*	*camaldulensis* Dehnh.	River red gum (E)	[13] Australia	Australia	u	3
Myrtaceae	*Eucalyptus*	*ficifolia* F. Muell.	Red-flowering gum (E)	[13] Southwestern Australia	Australia	u	9
Myrtaceae	*Eucalyptus*	*globulus* Labill.	Blougom (E)	[13] Southwestern Australia	Australia	u	11, 33
Myrtaceae	*Eucalyptus*	*grandis* W.Hill ex Maiden	Flooded or rose gum (E)	[13] Eastern Australia	Australia	u	41
Myrtaceae	*Eucalyptus* L'Hér.	sp.	unknown	unknown	unknown	s & u	12, 37
Myrtaceae	***Melaleuca***	***leucadendron* (L.) L.**	Long-leaved paperbark (E)	[13] Australia; Malaysia	Asia; Australia	s & u	40
Myrtaceae	*Myrtus*	*communis* var.	Myrtle (E)	[13] Mediterannean region	Africa; Europe; Asia	u	3
Myrtaceae	*Psidium*	*guajava* L.	Guava (E)	[13] Tropical America	N & S America	u	8, 14, 21, 41
Nyctaginaceae	*Mirabilis*	*jalapa* L.	Four-o' clock (E)	[13] Central America	North America	u	3
Oxalidaceae	*Oxalis*	*corniculata* L.	Jimson weed; Creeping sorrel (E)	[20] Britain	Europe	u	3
Papaveraceae	*Argemone*	*ochroleuca* subsp. *ochroleuca*	Mexican poppy (E)	[11] Mexico; Texas	North America	u	3
Papaveraceae	*Argemone*	*mexicana* L.	Devil's fig; Golden thistle of Peru (E)	[21] Mexico	North America	u	9
Papaveraceae	*Eschscholzia*	*californica* subsp. *californica*	California poppy (E)	[13] California	North America	u	3

Family name	Genus	Species	Common name (s)	** Origin	Continent	Sold (s) / Used (u)	Reference#
Passifloraceae	*Passiflora*	*coerulea* L.	Blue passion-flower (E)	[13] Brazil-Argentina	South America	u	3
Passifloraceae	*Passiflora*	*edulis* Sims.	Purple granadilla (E)	[13] Brazil	South America	u	3
Passifloraceae	*Passiflora*	*suberosa* L.	Devil's pumpkin; Indigo berry (E)	[13] Central and Southern America	N & S America	s & u	35
Pedaliaceae	*Ibicella*	*lutea* (Lindl.) Van Eselt.	Yellow devil's claw; Yellow martynia (E)	[11] Brazil; Uruguay; Paraguay; Argentina	South America	s & u	39
Pedaliaceae	*Sesamum*	*orientale* L.	Sesame (E)	[11] Africa; Asia; Australia	Africa; Asia; Australia	u	3
Periplocaceae	*Persea*	*americana* var. Mill.	Avocardo (E)	[13] Central America	North America	s & u	8
Phytolaccaceae	*Phytolacca*	*americana* L.	unknown	[13] Eastern USA	Europe	u	15
Phytolaccaceae	*Phytolacca*	*dioica* L.	Belhambra; Pokeberry tree (E)	[13] South America	South America	s & u	3, 35
Phytolaccaceae	*Phytolacca*	*octandra* L.	Calalu (E)	[22] Tropical America from Mexico to Columbia	N & S America	u	25
Pinaceae	*Pinus*	*roxburghii* Sarg.	Chir pine (E)	[13] Himalayas	Asia	u	3
Pinaceae	*Pinus* L.	sp.	Pine (E)	unknown	unknown	s & u	7, 11, 12, 37
Plantaginaceae	*Plantago*	*lanceolata* L.	Weeblaar (Afr)	[25] Europe, Asia	Europe; Asia	u	33
Plantaginaceae	*Plantago*	*major* L.	Common plantain (E)	[26] Afghanistan	Asia	u	3, 14, 18, 34
Plumbaginaceae	*Plumbago*	*zeylanica* L.	Ceylon leadwort; White flowered leadwort (E)	[1] Tropics of Asia and Africa; East of Australia; Hawaii	North America; Africa; Asia; Australia	u	3
Poaceae	*Aira*	*cupaniana* Guss.	unknown	unknown	unknown	u	3
Poaceae	*Anthoxanthum*	*odoratum* L. var. *odoratum*	Sweet vernal grass (E)	[13] Eurasia	Europe; Asia	u	3
Poaceae	*Arundo*	*donax* L.	Bamboo reed; Giant reed; Reed; Spanish reed (E)	[20] Southern Europe	Europe	u	3
Poaceae	*Avena*	*fatua* L.	Wild oat (E); Tartarean oat (E); Gewone wilde hawer (Afr)	[16] Europe; Asia	Europe; Asia	u	3
Poaceae	*Avena*	*sativa* L.	Oats (E)	[13] Northern Temperate regions	North America; Europe; Asia	u	3
Poaceae	*Bromus*	*catharticus* Vahl.	Rescue grass (E)	[13] Garden origin	Garden origin	u	3
Poaceae	***Coix***	***lacryma-jobi* L.**	Job's tears (E)	Papua New Guinea	Australia	s & u	3, 14, 40
Poaceae	*Cynodon*	*aethiopicus* Clayton & Harlan	Giant quickgrass; Giant star grass (E)	[4] East Africa; Ethiopia-Namibia, Botswana and Mozambique	Africa	u	3
Poaceae	*Dactylis*	*glomerata* L.	Cocksfoot (E)	[13] Eurasia	Europe; Asia	u	3
Poaceae	*Digitaria*	*sanguinalis* (L.) Scop.	Crab grass; Crop grass; Early crab grass (E)	[32] Indonesia	Asia	u	3
Poaceae	*Elytrigia*	*repens* (L.) Nevski.	unknown	unknown	unknown	u	3
Poaceae	*Hordeum*	*murinum* L.	Wild barley; Barley-grass; Foxtail (E)	unknown	unknown	u	3
Poaceae	*Lolium*	*perenne* L.	Perennial ryegrass (E)	[13] Eurasia	Europe; Asia	u	3
Poaceae	*Lolium*	*temulentum* L.	Darnel (E)	[13] Eurasia	Europe; Asia	u	3
Poaceae	*Paspalum*	*dilatatum* Poir.	Dallis grass (E)	[11] South America	South America	u	3
Poaceae	*Pennisetum*	*clandestinum* Chiov.	Kikuyu grass (E)	[13] Tropical Africa	Africa	u	3
Poaceae	*Pennisetum*	*glaucum* (L.) R.Br.	Pearl millet (E)	[13] Tropical Africa	Africa	u	3
Poaceae	*Pennisetum*	*purpureum* Schumach.	Elephant or Napier grass (E)	[13] Tropical Africa	Africa	u	3
Poaceae	*Poa*	*annua* L.	Annual Meadow Grass (E)	[13] Europe	Europe	u	3
Poaceae	*Setaria*	*italica* P. Beauv	Bengal grass; Italian millet; Japanese millet (E)	[17] Asia	Asia	u	3
Poaceae	*Sorghum*	*halepense* (L.) Pers	Johnson grass (E)	[13] Europe; Asia	Europe; Asia	u	3
Poaceae	*Vetiveria*	*zizanioides* (L.) Nash	Vetiver (E)	[13] Asia	Asia	u	14
Polygonaceae	*Fagopyrum*	*esculentum* Moench	Buckwheat (E)	[13] Asia	Asia	u	3
Polygonaceae	*Persicaria*	*hydropiper* (L.) Spach	unknown	unknown	unknown	u	3
Polygonaceae	*Persicaria*	*lapathifolia* (L.) Gray	Spotted knotweed (E)	unknown	unknown	u	3, 14
Polygonaceae	*Polygonum*	*aviculare* L.	Bird Knotgrass; Bird Knotweed; Hogweed (E)	[14] Temperate Europe	Europe	u	32
Polygonaceae	*Rumex*	*acetosella* L.	Common field; Sheep sorrow (E)	unknown	unknown	u	10
Polygonaceae	*Rumex*	*crispus* L.	Curled dock (E)	[13] Europe; Asia	Europe; Asia	s & u	8, 11, 37
Portulacaceae	*Portulaca*	*oleracea* L.	Purslane (E)	[20] Tropics	N & S America; Africa; Asia; Australia	u	3
Primulaceae	*Anagallis*	*arvensis* L. subsp. *arvensis*	Blue pimpernel (E)	[13] Cosmopolitan distribution	Cosmopolitan distribution	u	3

Family name	Genus	Species	Common name (s)	** Origin	Continent	Sold (s) / Used (u)	Reference#
Proteaceae	***Macadamia* F.Muell.**	**sp.**	Macadamia nut	[13] Eastern Australia	Australia	s & u	40
Punicaceae	*Punica*	*granatum* L.	Granaat (Skille); Granaatbas (E)	[13] Turkey-Central Asia	Asia	u	3, 23, 33
Ranunculaceae	*Ranunculus*	*multifidus* Forssk.	Buttercup (E)	[43] United States	North America	u	15
Rosaceae	*Cydonia*	*oblonga* Mill.	Quince (E)	[45] Cultivated	unknown	u	3
Rosaceae	*Duchesnea*	*indica* (Andrews) Focke	Indian strawberry (E)	[13] China; India	Asia	u	3
Rosaceae	*Eriobotrya*	*japonica* (Thunb.) Lindl.	Loquat	[13] China; Japan	Asia	s & u	8
Rosaceae	*Fragaria*	*vesca* L.	Alpine strawberry (E)	[20] Europe	Europe	u	3
Rosaceae	*Prunus*	*persica* var. *persica*	Peach (E)	[13] Northern and Central China	Asia	u	3
Rubiaceae	*Richardia*	*brasiliensis* Gomes	Mexican clover; Mexican richardia (E)	[11] South America	South America	u	3
Rutaceae	*Citrus*	*limon* (L.) Burm.f.	Lemon (E)	[13] Southeastern Asia	Asia	u	17, 41
Rutaceae	*Ruta*	*graveolens* L.	Rue; Herb of grace (E)	[13] Europe	Europe	u	9, 32, 34
Salicaceae	*Populus*	*canescens* (Aiton) Sm.	Grey poplar (E)	[20] Britain	Europe	u	3
Salicaceae	*Salix*	*babylonica* L. var. *babylonica*	Weeping willow (E)	[13] Asia	Asia	u	32
Sapindaceae	*Cardiospermum*	*halicacabum* L. var.	unknown	[13] Pantropical regions	Africa; Asia; Australia	u	18
Simaroubaceae	*Ailanthus*	*altissima* (Mill.) Swingle	Tree-of-heaven (E)	[13] China	Asia	u	26
Solanaceae	*Cestrum*	*laevigatum* Schltdl.	Inkberry (E)	[13] Brazil	South America	u	3
Solanaceae	*Datura*	*ferox* L.	Large thorn apple (E)	[13] Argentina	South America	u	8, 30
Solanaceae	*Datura*	*inoxia* Mill.	unknown	[13] Mexico; West Indies	North America	u	3
Solanaceae	*Datura*	*metel* L.	Thorn apple; Hairy thorn apple ; Recurved thorn apple (E)	[10] America	N & S America	s & u	3, 15, 39
Solanaceae	*Datura*	*stramonium* L.	Thorn apple (E)	[6] Eastern North America, central and South America	N & S America	s & u	3, 9, 14, 18, 29, 31, 37
Solanaceae	*Nicandra*	*physalodes* (L.) Gaertn.	Shoo-fly (E)	[13] Peru	South America	u	3
Solanaceae	*Nicotiana*	*glauca* Graham	Wild tobacco (E)	[13] Argentina; Bolivia	South America	u	8, 11, 32
Solanaceae	*Nicotiana*	*tabacum* L.	Tobacco (E); Tabak (Afr)	[13] South America	South America	u	2, 30
Solanaceae	*Physalis*	*angulata* L.	Ground cherry (E)	[16] N & S America; Africa; Asia; Australia	N & S America; Africa; Asia; Australia	u	3
Solanaceae	*Physalis*	*minima* L.	Gooseberry (E)	unknown	Europe; Asia	u	3
Solanaceae	*Physalis*	*peruviana* L.	Cape gooseberry (E)	[13] Bermuda-Peru	Europe; Asia	u	3, 8, 15
Solanaceae	*Solanum*	*mauritianum* Scop.	Bug tree (E)	[13] South America	South America	u	3, 9, 14, 18
Solanaceae	*Solanum*	*pseudocapsicum* L.	Jerusalem cherry (E)	[13] South America	South America	u	3
Solanaceae	*Solanum*	*rostratum* Dunal.	Buffalo bitter apple; Hedgehog bush; Sandbur (E)	[11] North America	North America	u	3
Solanaceae	*Solanum*	*americanum* Mill.	Black nightshade (E)	[13] Cosmopolitan distribution?	Cosmopolitan distribution?	u	10, 15
Solanaceae	***Withania***	***somnifera* (L.) Dunal**	Winter cherry (E)	[24] Africa; Europe; Asia	Africa; Europe; Asia	s & u	6, 7, 8, 13, 17, 37, 40
Solanaceae	*Datura* L.	sp.	unknown	unknown	unknown	u	33
Urticaceae	*Pilea*	*microphylla* (L.) Liebm.	Artillery plant (E)	[13] Mexico-Brazil	N & S America	s & u	8
Urticaceae	*Urtica*	*dioica* L.	Stinging nettle (E)	[13] Europe; Asia	Europe; Asia	u	11, 32
Urticaceae	*Urtica*	*urens* L.	Stinging nettle (E)	[23] Europe	Europe	u	6, 14, 18
Verbenaceae	*Duranta*	*erecta* L.	Pigeon-berry; Golden dewdrop; Forget-me-not tree (E)	[13] Florida; Brazil	N & S America	u	3
Verbenaceae	*Verbena*	*fordii* (Hemsl.) Airy Shaw	Tungoil tree (E)	unknown	North America; Europe; Asia	u	3
Verbenaceae	*Verbena*	*officinalis* L.	Vervain; Juno's tears (E)	[13] North America; Europe; Asia	North America; Europe; Asia	u	3
Verbenaceae	*Verbena*	*rigida* Spreng	unknown	[37] South America	South America	u	3
Violaceae	*Hybanthus*	*enneaspermus* var.	Pink ladies-slipper (E)	unknown	North America	u	14
Violaceae	*Viola*	*tricolor* L.	Heart's ease; Love-in-idleness; Pansy (E)	[13] Europe	Europe	u	3
Zingiberaceae	***Curcuma***	***longa* Linn**	Tumeric (E)	unknown	unknown	s & u	40
Zingiberaceae	***Hedychium***	***gardnerianum* Ker Gawl.**	kahili ginger (E), wild ginger (E)	[13] Himalayas	Asia	s & u	40
Zingiberaceae	*Zingiber*	*officinale* Roscoe	Ginger (E); Gemmer (Afr)	[13] Asia	Asia	u	31

Family name	Genus	Species	Common name (s)	** Origin	Continent	Sold (s) / Used (u)	Reference#
uniden. 1			**avalkadle (I)**	unknown	Indian import	s & u	40
uniden. 2			**dumapansi (Z)**	unknown	Indian import	s & u	7, 40
uniden. 3			**girmalasing (I)**	unknown	Indian import	s & u	40
uniden. 4			**ibande (Z)**	unknown	unknown	s & u	40
uniden. 5			**inderjow (I)**	unknown	Indian import	s & u	40
uniden. 6			**indian pearls; indian peanuts; indian beans; indian nut (E); jamal gota (I)**	unknown	Indian import	s & u	40
uniden. 7			**inhlanhla emhlophe (Z)**	unknown	unknown	s & u	40
uniden. 8			**iphengula (Z)**	unknown	unknown	s & u	40
uniden. 9			**kachka (I)**	unknown	Indian import	s & u	40
uniden. 10			**kamal kadi; kamal kachie (I); impitie (Z)**	unknown	Indian import	s & u	40
uniden. 11			**kapoor kachi (I)**	unknown	Indian import	s & u	40
uniden. 12			**unukani oyikhambi (Z)**	unknown	unknown	s & u	40

Reference to studies

Reference#: 1 = (Appidi *et al.* , 2008); 2 = (Archer, 1990); 3 = (Arnold *et al.* , 2002); 4 = (Bhat and Moskovitz, 2009); 5 = (Botha *et al.* , 2001); 6 = (Bryant, 1966); 7 = (Cunningham, 1988); 8 = (Diederichs, 2001); 9 = (Dold and Cocks, 2000); 10 = (Dold and Cocks, 1999); 11 = (Future Works, c. 2008); 12 = (Grace *et al.* , 2003); 13 = (Grierson and Afolayan, 1999); 14 = (Hutchings *et al.* , 1996); 15 = (Hutchings, 1989); 16 =(Koduru et al., 2007); 17 =(Lamla, 1981); 18 = (Lewu and Afolayan, 2009); 19 = (Liengme, 1981); 20 = (Loundou, 2008); 21 = (Mabogo, 1990); 22 = (Mander, 1997); 23 = (Mathabe *et al.* , 2006); 24 = (Ndawonde *et al.* , 2007); 25 = (Stafford *et al.* , 2005); 26 = (Stafford *et al.* , 2008); 27 =(Steenkamp, 2003); 28 = (Tait and Cunningham, 1988); 29 = (Thring and Weitz, 2006); 30 = (Van Wyk and Gericke, 2000); 31 = (Van Wyk *et al.* , 1997); 32 = (Van Wyk *et al.* , 2008); 33 = (Van Wyk, 2008); 34 =(Veale et al., 1992); 35 = (Von Ahlefeldt et al., 2003); 36 =(Williams et al., 2000); 37 =(Williams et al., 2001); 38 =(Williams et al., 2007b); 39 = (Williams, 2007c); 40 =(Wojtasik, in prep); 41 = (York et al., 2011).

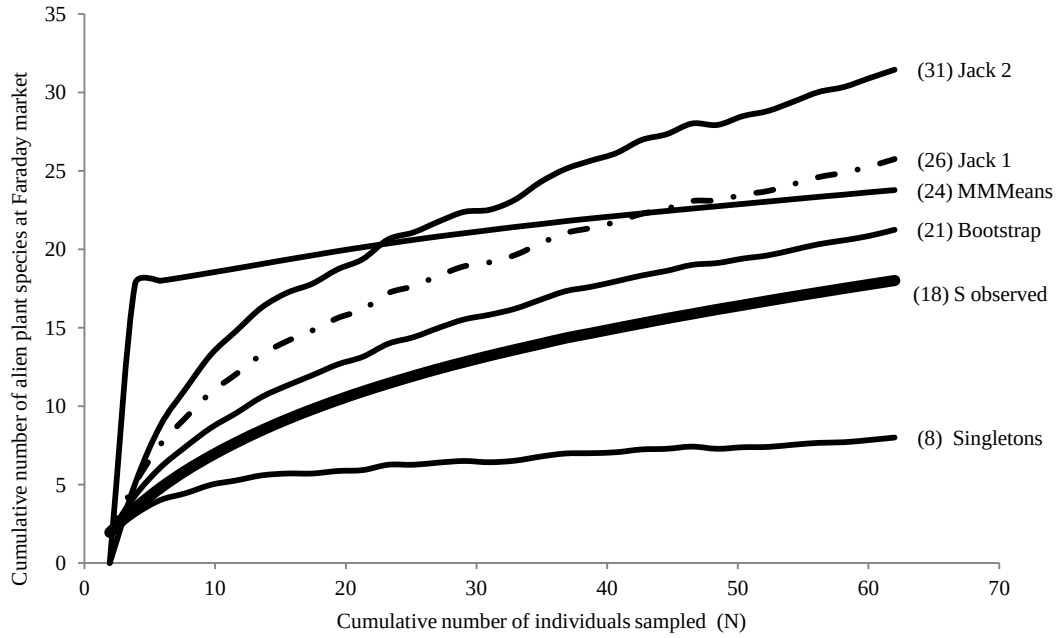
References to sources that cited origins of the alien plant species

1 = (Bailey, 1947); 2 = (Beentje et al., 2005); 3 = (Burkill, 1985a); 4 = (Burkill, 1985b); 5 = (Burkill, 1985c); 6 = (Burkill, 1985d); 7 = (Carter and Leach, 2001); 8 = (Dakshini, 1984); 9 = (De Lange et al., 2004); 10 = (Edmonds, 2006); 11 = (Everett, 1980); 12 = (Exell, 1961); 13 = (Glen, 2002); 14 = (Graham, 1958); 15 = (Harvey, 1894); 16 = (Hedrick, 1972); 17 = (Hirano et al. 2011); 18 = (Klein, 2011); 19 = (Liu et al. 2006); 20 = (Macself, 1945); 21 = (Morley, 1974); 22 = (Polhill, 1971); 23 = (Roux, 2003); 24 = (Van Wyk et al., 1997); 25 = (Verdcourt, 1971); 26 = *Afghanistan, Kurum Valley. Kurum and Hariáb Districts. 1879-06-06, Aitchison, J.E.T. #516 (K), seen on http://apps.kew.org/herbcat/; 27 = *Argentina, 1837, Tweedie, #s.n. (K), seen on http://plants.jstor.org/specimen; 28 = *Belguim, Belgien. Köts...brod. Pillnitz-Briesnitz, Lejeune, A.L. #659 (S), seen on http://plants.jstor.org/specimen; 29 = *Brazil, 1818-09, Wied, M. #s.n.(BR), seen on http://plants.jstor.org/specimen; 30 = *Côte d'Ivoire, 1952-11-22, Morton, J.K. #8001 (BM), seen on http://plants.jstor.org/specimen; 31 = *France, Cerdagne, 1929-8-23, Sennen , F. #7068 (PH), seen on http://plants.jstor.org/specimen; 32 = *Indonesia, Batavia, 1875-05, Kuntze, C.E.O. #4201 (NYBG), seen on http://plants.jstor.org/specimen; 33 = *Indonesia, Java, von Blume, C.L. #s.n. (NYBG), seen on http://plants.jstor.org/specimen; 34 = *Mexico, Minas de San Rafael, 1911-07, Carl Albert Purpus #5237 (BM), seen on http://plants.jstor.org/specimen.; 35 = *Morocco, 1939-6-16, R. Maire, #72 (MPU), Seen on http://plants.jstor.org/specimen; 36 = *Paraguay, 1897, Hassler, E. #3711 (BM), seen on http://plants.jstor.org/specimen; 37 = *Paraguay, 1919-02, Rojas, T. #3407 (M), seen on http://plants.jstor.org/specimen (Holotype); 38 = *Peru, Lurin, Cruckshanks #s.n. (K), seen on http://apps.kew.org/herbcat; 39 = *Spain, Menorca, 1913-4-20, Font Quer, #s.n. (MA), seen on http://plants.jstor.org/specimen; 40 = *Sweden, Uppsala, Anon #1744 (LINN), seen on http://plants.jstor.org/specimen (lectotype); 41 = *United States, Courtney, 1903-10-5, Bush, B.F, #1916 (MO), seen on http://plants.jstor.org/specimen ; 42 = *United States, Texas , 1894-6-26, Heller, A.A. #1918 (PH), seen on http://plants.jstor.org/specimen; 43 = *United States, Utah, Weber Valley, 1868, Watson, S. #24 (US), seen on http://plants.jstor.org/specimen (holotype); 44 = Global invasive species database, http://www.issg.org/database/species/ecology.asp?fr=1&si=1426; 45 = Tropicos website [http://www.tropicos.org/name/27801567?projectid=22];

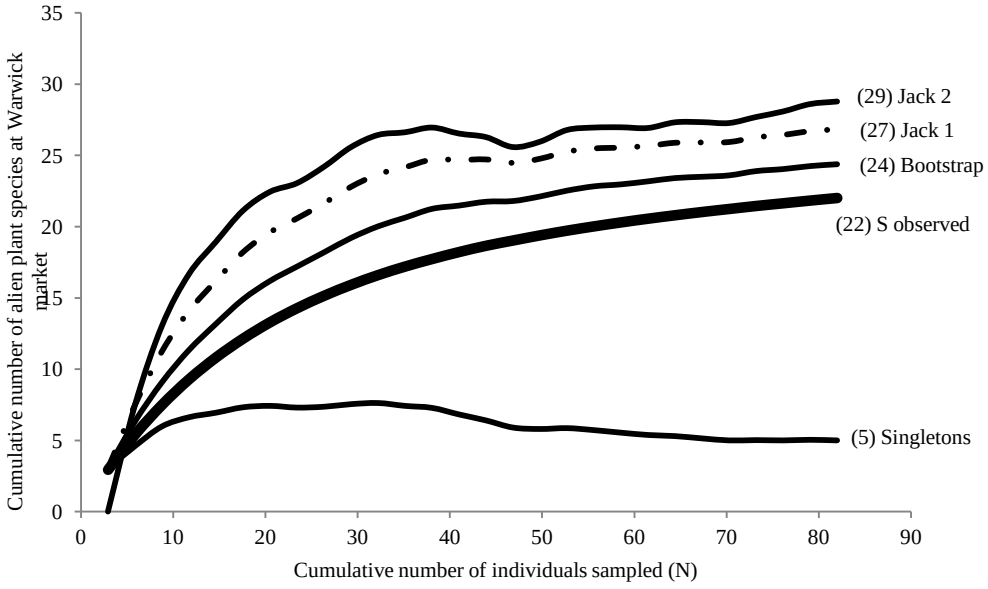
Appendix 6: Species Richness Estimator graphs

Cumulative number of individuals (N) versus the cumulative number of alien plant species. These graphs indicate how many alien plant species were estimated to be at each outlet i.e. TM market or MS by various species richness estimators. Species estimators included: Bootstrap, MMMeans, First-order Jack (Jack 1) and second-order Jack (Jack 2). Numbers in brackets are the number of alien plant species estimated by that particular species richness estimator. 'S observed' referred to the actual number of alien species that were recorded at that specific outlet.

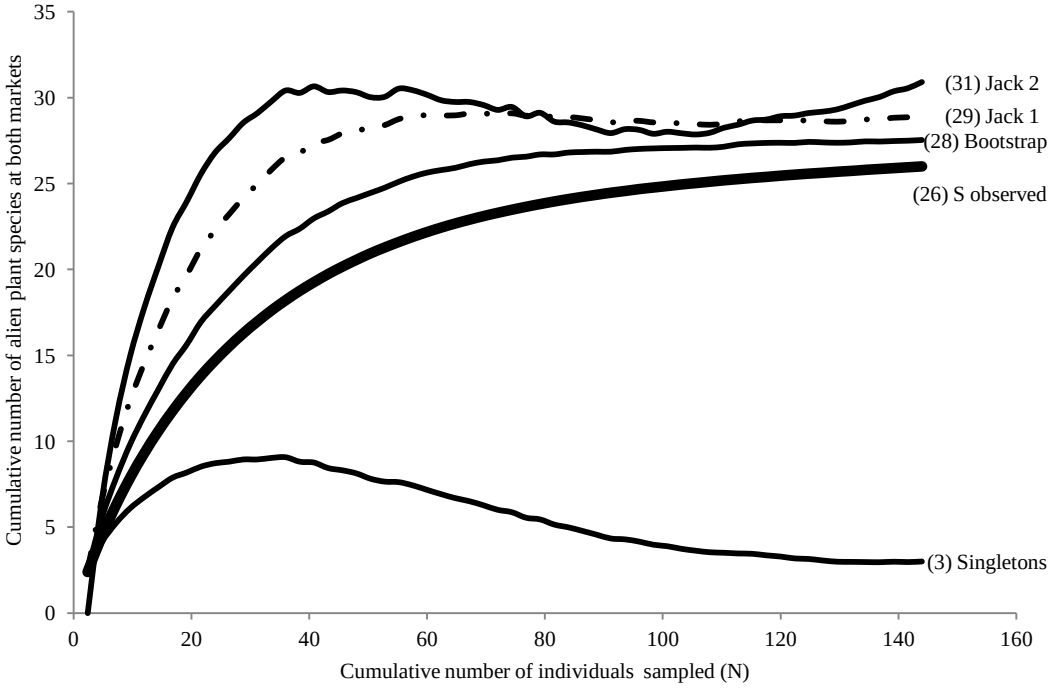
a) Faraday market



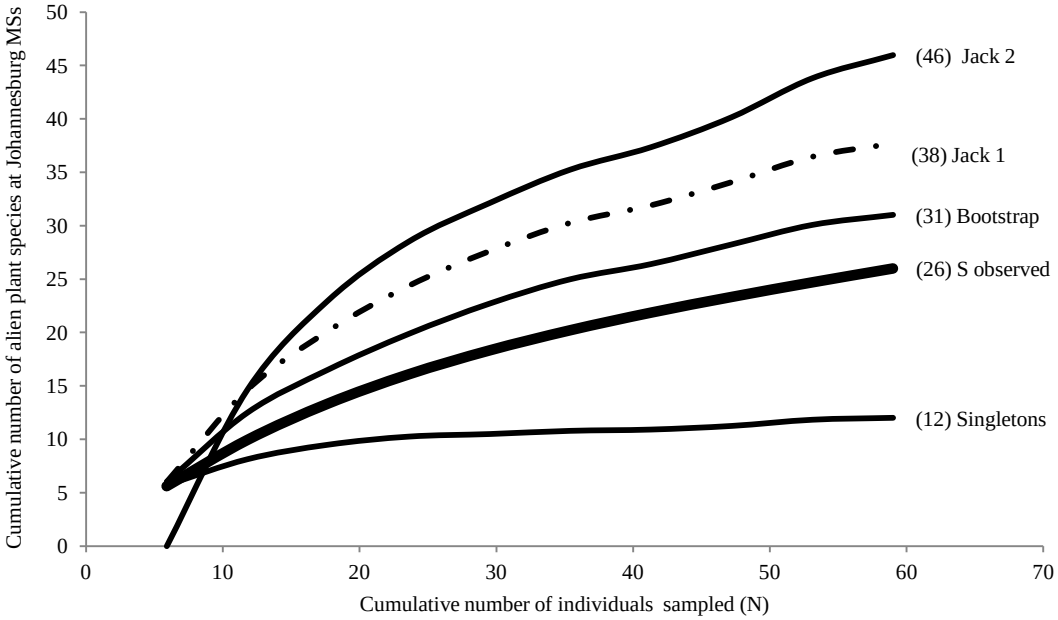
b) Warwick market



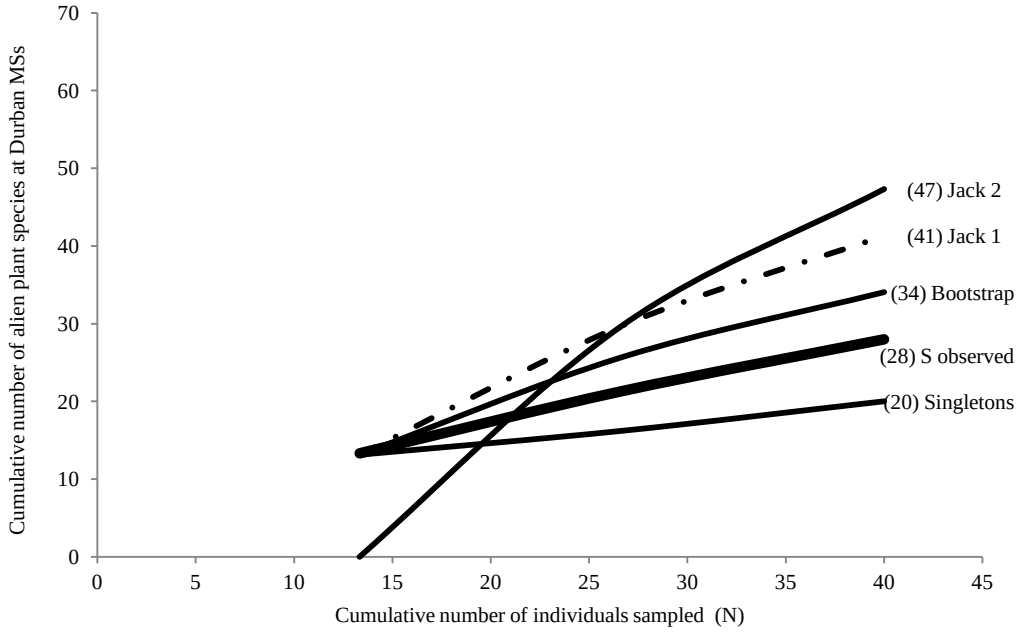
c) Both markets



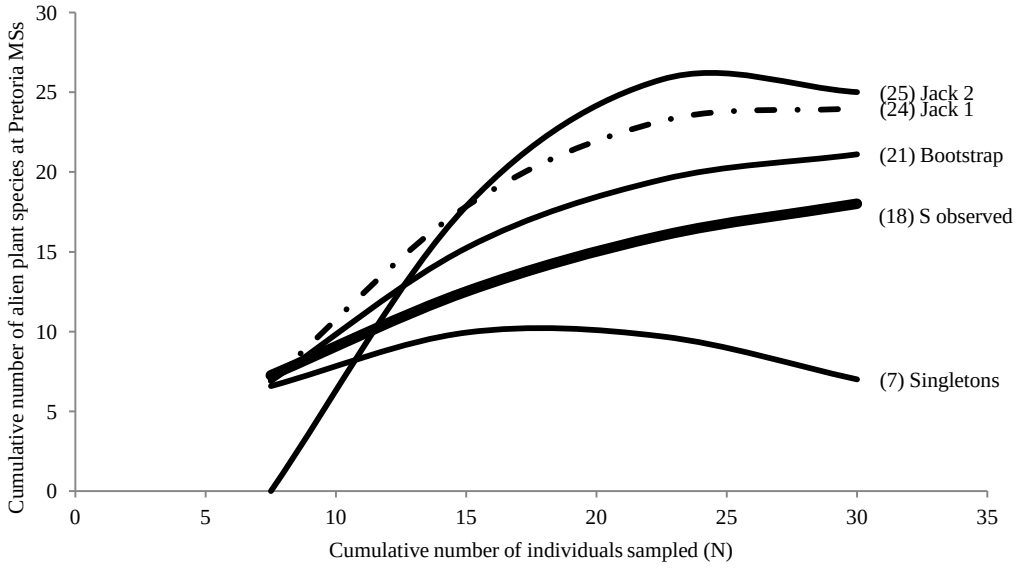
d) Johannesburg *muthi* shops



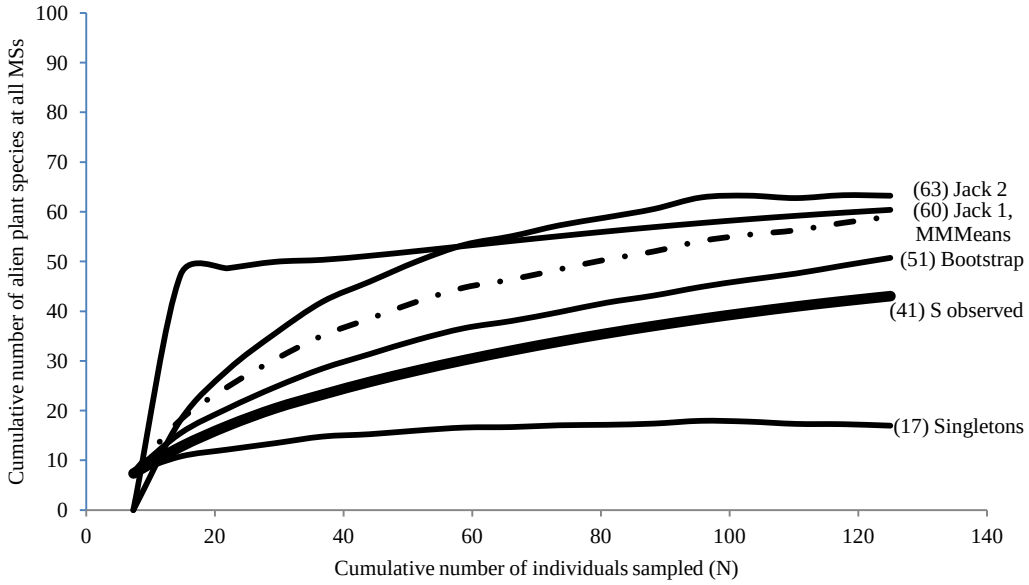
e) Durban *muthi* shops



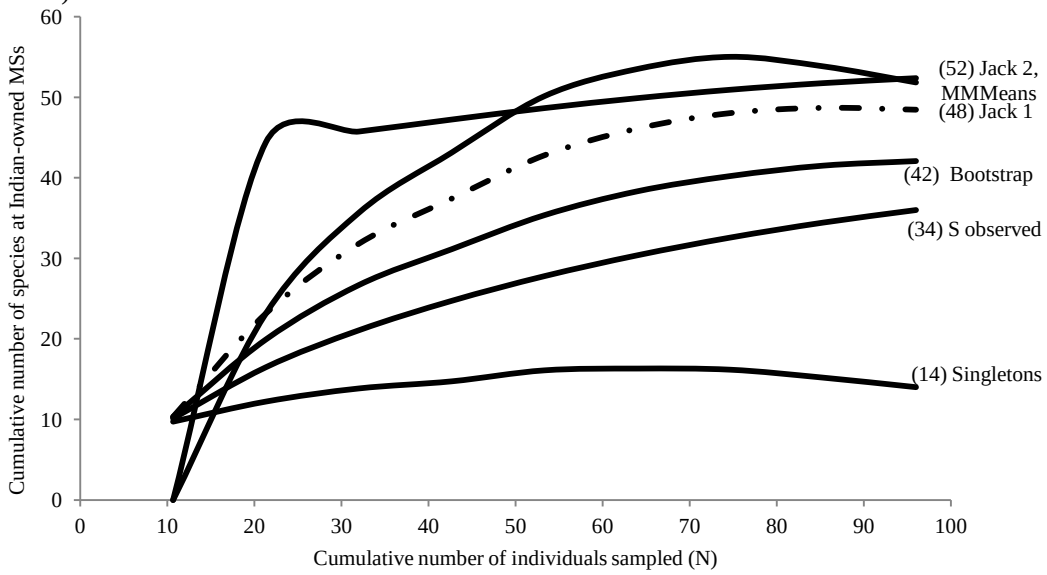
f) Pretoria *muthi* shops



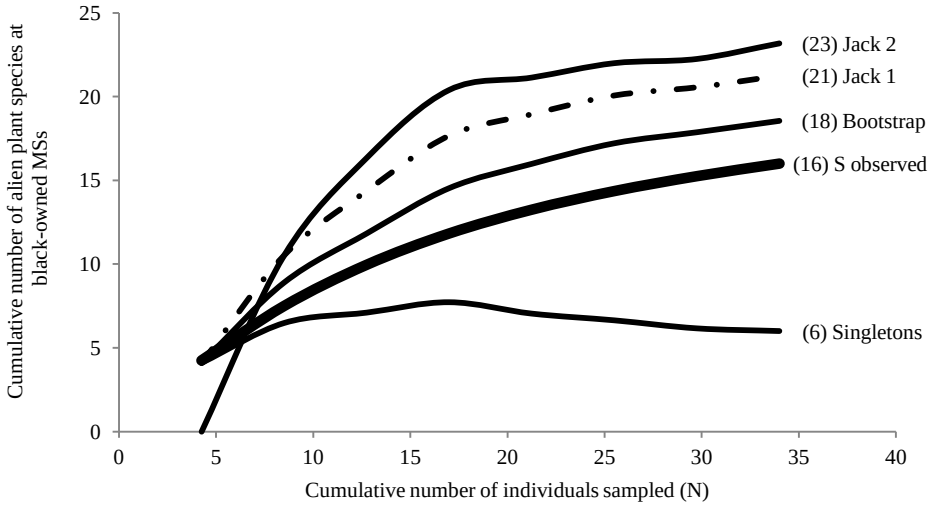
g) All *muthi* shops



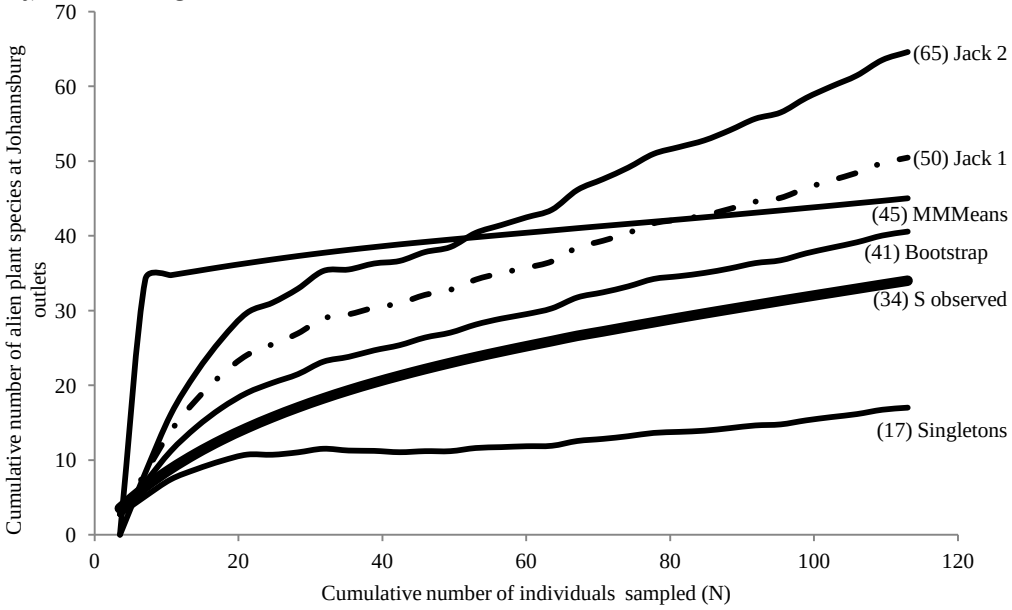
h) Indian-owned MS



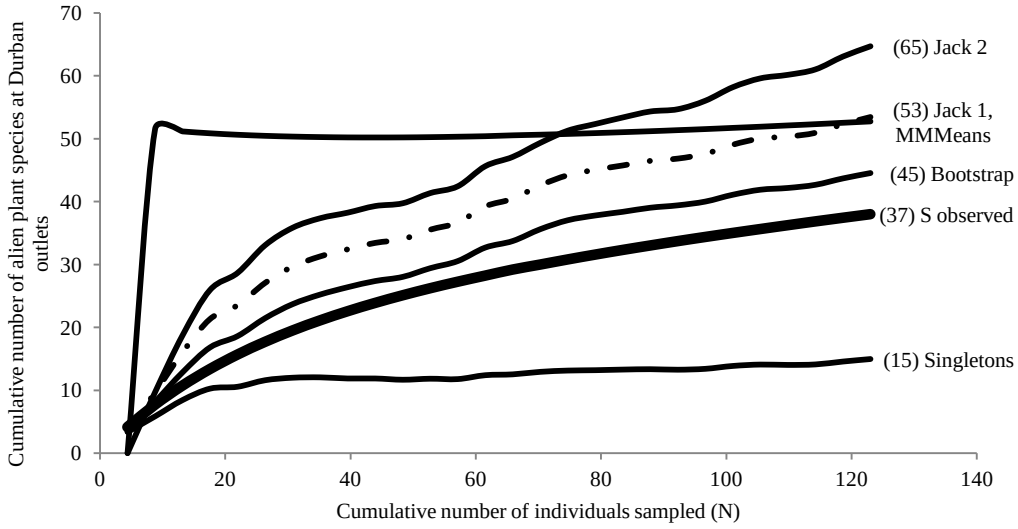
i) Black-owned MS



j) Johannesburg overall



k) Durban overall



l) Whole data set

