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A SURVEY OF THE EXOTIC WOODY PLANT SPECIES IN THE CITY OF GABORONE, BOTSWANA

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ABSRACT

A survey of the exotic woody plants species was conducted in the city of Gaborone. A total of eleven sites (treatments 1 to 11); Segoditshane, Gaborone west, Phase II, Block 8, Block 6, Block 5, Bontleng, Gaborone village, Maruapula, Broadhurst and Ledumang were randomly selected from the total number of eighteen (18) sites using the geographical map of the city of Gaborone. A street name was randomly picked from each site and used as the baseline. An area of 400 m × 100 m was measured along the baseline for each site. The area was then subdivided into three quadrants (replications) of 100 m × 100 m size, spaced 50 m apart. The middle quadrant was taken as the first replication, second and third were the ones on the right and left, respectively facing the North. Twenty-six (26) families were documented for the 40 species found in the surveyed sites. It was observed that the Leguminosae family had more species occurring in the Gaborone area with a total number of five genera. The other families had three or fewer genera which were observed in the surveyed sites. Sites within the Gaborone area were significantly ($p<0.01$) different. The Segoditshane site which lies along a stream had the highest mean whereas Block 6 site had the least mean of exotic plants species. Despite differences in absolute numbers, the total means for treatments 3, 7, 9, 10 and 11 did not exhibit significant ($p>0.05$) differences. Moreover, in terms of the number of individual species, Dodonea viscosa and Tecoma stans had the highest number of occurrence whereas Ficus carica and Callistemon viminalis had the least numbers. The survey showed that a higher number of exotic plants occur in the city of Gaborone. The exotic plants species are either introduced by human being or through natural means. Therefore relevant authorities need to put in place appropriate measures to control the spread of invasive exotic plants species.

KEYWORDS Exotic plants species; Indigenous plants species; City of Gaborone; Landscape

1 INTODUCTION

Exotic plants are non-native species that grow outside their natural adapted ranges and dispersal potential (Randall, 1996). Exotic plant species become invasive when they are deliberately or intentionally planted outside their natural range into new areas where they are able to establish themselves and quickly invade and out-compete native plant species for resources (Randall, 1996; Williamson, 1996; Akter and Zuberi, 2009). Exotic plant species are aggressive competitors (Sumners and Archibold, 2007) which are characterised by high population growth rates and reproductive capacities, short life cycles, easily dispersed seeds and efficient uses of water and nutrients (Orians, 1986; Kolar et al., 2001). Moreover, they are able to establish self-producing populations in the wild can lead to changes in the local, artificial or natural ecosystems (Williamson, 1996; Akter and Zuberi, 2009). Many of these exotic plant species had been introduced to new habitats by humans (Ridenour and Callaway, 2001; Dogra et al., 2010) for economic reasons. However, some have been introduced to new areas through birds, animals, water and wind dispersal (Herbold et al., 1986). The introduction of exotic plant species by humans increased significantly during the last five centuries, especially during the turn of the 20th century, due to rapid increase in global trade and travel (Dogra et al., 2010). Aeroplanes, ships and other forms of transport have allowed both deliberate and inadvertent movement of plant species often resulting in unexpected and sometimes serious invasions (Moore, 2004). According to Fox and Fox (1986) and Hobs (1991)

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natural ecosystems disturbances can facilitate invasion by overcoming physical and environmental barriers. Such changes in ecosystems may significantly modify ways in which local systems interact with surrounding ecosystems, with downstream ecosystems and groundwater as well as the atmosphere (Vitousek, 1992).

The invasion by alien or exotic plant species represents an ecological risk to indigenous plants world-wide (Kil et al., 2004). Both the disturbed and unmanaged habitats are more susceptible to the invasion as compared to the well-managed counterparts (Crawley, 1987). The invasion by exotic plant species has become a threat to the natural environment (Vitousek et al., 1996) and ecosystems (Randall, 1996; Kaiser, 1999; Hulme, 2003; Simberloff, 2005) because they negatively affect the invaded habitats and thus alter the indigenous plant species diversity, soil nutrient composition and forest fire cycles in addition to reducing surface water runoff and groundwater reserves, increasing biomass and loss of productivity of invaded ecosystems (Pimentel et al., 2005; Dogra et al., 2010). The negative effects of invasive exotic or alien species on indigenous species are well documented (Coblentz, 1990; Vitousek et al., 1996; Richardson et al., 2000; Holway et al., 2002; Carlton, 2003; Kil et al., 2004; Ortega and Pearson, 2005; Pimentel et al., 2005; Dogra et al., 2010). Richardson et al. (2000) estimated that about 50% of invasive species can be classified as ecologically harmful, based on their actual impacts on the environment. However, invasive alien plant species can positively contribute to rural economies (Semenya et al., 2012) through provision of goods and services.

Botswana, like other countries elsewhere introduced exotic woody species from different countries for the provision of a wide range of products and services, where native tree species were not suitable. Exotic woodlots comprising mainly of Eucalyptus were established at the turn of the 20th century to supply timber for the provision of fuelwood and poles for general farm construction. In addition to woodlots, numerous exotic woody species have been planted for ornamental aesthetic value such as planting along streets, parks, offices and around homesteads in both urban and rural areas. However, some exotic trees introduced to Botswana have become invasive, which is evident along roads and streams around cities, towns and major villages. Roads are common sites for exotic woody plant invasion and represent dispersal corridors in the landscape (Wilson et al., 1992; Londale and Lane, 1994). Streams may also serve as corridors for dispersal of plants (Gregory et al., 1991) including exotic species (Pysek and Prach, 1993; Pyle, 1995). Although exotic woody species provide important good and services to society in Botswana, information on the extent of their invasion is lacking. Therefore, the present survey was conducted to investigate the extent of invasive woody species in the city of Gaborone.

2 MATERIALS AND METHODS

2.1 Study area

The study was conducted within Gaborone, the capital city of Botswana. The city lies at latitude 24º39‘S, longitude 25º55‘E and at approximately 968 m above sea level. The climate of the study area is semi-arid, with a long-term annual average rainfall of 526 mm with a seasonal variation. The majority of rainfall occurs in a relatively small number of intense rainstorms, generally of short duration and occur between the months of October and March. Soils in the study area are dominated by sandy gravels and clay soils. The vegetation is composed of different types of plants both indigenous and exotic.

2.2 Data collection

A geographical map of Gaborone obtained from the Department of Surveys and Mapping was used to randomly pick a total of 18 sites within the area as follows; Gaborone west, Phase II, Block 3, Block 5, Block 6, Block 7, Block 8, Block 9, Block 10, Maruapula, Broadhurst, Ledumang, Gaborone village, Bontleng, Extension 2, Segoditshane, Naledi and Phakalane. Thereafter, each name was individual written on a piece of a paper and eleven (11) sites were picked at random to achieve more than 60% representative of the entire area. The following sites were randomly picked; Segoditshane, Gaborone west, Phase II, Block 8, Block 6, Block 5, Bontleng, Gaborone village, Maruapula, Broadhurst and Ledumang being treatments 1 to 11 respectively.

The map was then used to randomly pick the street names to be used as a baseline for each site. Along the baseline for each site, an area of 400 m ×

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100 m was measured and thereafter subdivided into three quadrants (replications) of 100 m × 100 m size, spaced 50 m apart. The middle quadrant was taken as the first replication, second and third were the ones on the right and left, respectively facing the north. All exotic plant species in each quadrant were counted and recorded using their family names, scientific names, common names and their quantities based on the occurrences of each species.

2.3 Data Analysis

The data collected was subjected to analysis of variance (ANOVA) using the STATISTIX-8 program. Treatment means were separated using Tukey's Studentized Range (HSD) Test at $p \leq 0.05$.

3 RESULTS AND DISCUSSION

3.1 Documentation of plant species

The species found were identified to the scientific names and the common names. The abbreviations were used to distinguish the species as in Table 1.

A total of twenty-six (26) families were documented for the 40 species found in the surveyed sites. The species belonged to different genera (Table 1). The introduction of exotic plant species has been reported to cause changes in the structure and composition of native plant communities (Rice and Emery, 2003) which could be occurring in the present study sites. Prior studies have reported that many exotic woody species introduced around the world for commercial and ornamental purposes have subsequently become noxious invaders (Higgins et al., 1999). The high number of exotic species observed in this study, probably suggest that they were introduced to the city for different purposes such as landscape decorations, planting for fruit production and even to provide shade. Native trees were not recorded in the present study, but field observations showed that their structure and composition has changed within the city of Gaborone as some areas are mostly dominated by the exotic woody species. The results of the present study show that the leguminosae family had more species with a total number of five genera. The other families in the city had three or less genera. This is an indication that exotic woody species dominate the woody vegetation in some parts of the city of Gaborone.

The high numbers of invasive exotic woody plant species observed in the city of Gaborone are likely to negatively affect the ecosystem and landscape by altering the chemical composition of the soil as well as the soil structure and reduce species that rely on indigenous plants. Most invasive exotic woody plants have a long taproot which enables them to utilise resources previously unavailable to indigenous species, such as deep water sources (Byers, 2002). The exotic trees species observed in the present study are likely to affect the growth of their indigenous counterparts and change their composition in the city of Gaborone. Studies conducted elsewhere found that that invasive exotic species negatively affect the diversity of indigenous plants species, soil ecology and dynamics, and agricultural ecosystem world-wide (Herbold et al., 1986).

There were significant differences across treatments (Figure 1) probably caused by several factors such as the number of people who plant trees for shade, live fence and ornamental. The differences could also be influenced by seed dispersal through water run-off, wind, birds and animals which is consistent with Dogra et al. (2010) who reported humans, birds, animals; water and wind are responsible for the spread of exotic trees species. The results of the present study show that Segoditshane which lies along a stream had the highest number of exotic trees species (Figure 1). This could be influenced by dispersal of seeds to the stream by water run-off and availability of moisture along the stream. This is consistent with Asaeda et al. (2011) who reported that floodplains of every river in Japan were invaded by exotic plants species. There is a possibility that the high number of exotic species observed along the Segoditshane could change the vegetation within the stream and reduce the run off in the long-term. Dogra et al. (2010) observed that invasive exotic trees species reduced surface water run-off and groundwater reserves, increase woody biomass and fire intensity and markedly reduce biodiversity with several negative economic effects.

The least number of exotic trees species was observed at Block 6 (Figure 1), probably because the area is new and people started building houses in the 1990s and not much tree planting has taken place. In addition, the area is mostly covered by institutional or company houses and occupants are probably reluctant to plant trees in rented property. The mean number of exotic trees species observed

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in treatment 3, 7, 9, 10 and 11 did not significantly differ (Figure 1). Most homesteads in these areas are owned by individuals who have planted *Dodonea viscosa* as a live fence and other exotic trees for shade and ornamental purposes. This could be significantly accelerating the spread of exotic woody species and may consequently alter the indigenous plant communities in the city of Gaborone as observed by Ridenour and Callaway (2001) elsewhere. Ridenour and Callaway (2001) reported that human introduced species increased during the last five centuries.

In terms of the number of individual species, *Dodonea viscosa* (DDV) and *Tecoma stans* (SLS) are the most dominant exotic woody plant species in the city of Gaborone (Figure 2). The dominance of *Dodonea viscosa* (DDV) could be attributed to it uses because it is commonly planted as a live fence or along with the wire fence as a wind breaker. *Tecoma stans* was abundant inside and outside homesteads, especially in disturbed and unmanaged areas than inside homesteads. This agrees with Crawley (1987) who found that disturbed and unmanaged areas were more susceptible to invasions than well-managed ecosystems and habitats. The two species are prolific producers of light seeds which are easily blown by wind and this could be aiding their spread and dominance in the city of Gaborone. Studies conducted elsewhere have shown that invasive exotic species can achieve high densities and dominate habitats because they have greater establishment success than their indigenous counterparts (Kolar et al., 2001; Ortega et al., 2005). The dominance of *D. viscosa* and *T. stans* probably suggest that their seeds germinate easily without any pre-sowing treatment when exposed to suitable environmental conditions which could also be accelerating their spread.

The invasion of habitats by introduced exotic woody species is complex phenomenon, which could lead to permanent changes in the structure of indigenous plants communities round the city of Gaborone as observed in other studies conducted elsewhere (Holway et al., 2002; Carlton, 2003). D'Antonio et al. (2001) reported that invasive exotic trees species pose a global threat to indigenous plants communities, especially in disturbed habitats.

Ficus carica (FCA) and *Callistemon viminalis* (CSV) had the least number of plants (Figure 2), probably because the two species are not suited to grow in the environment around the city of Gaborone. It is also possible that the two species are not prolific seed producers resulting to lower rate of seed dispersal. According to Dogra et al. (2010), the impact of natural invasion is similar to human made invasions, though this invasion depends mostly on the dispersal ability of the invading plants. The time scale for natural invasion can range from few years to several years. This means that if the rate of seeds dispersal is low, the plants can take a long time to invade the natural environment which probably applies to *Ficus carica* and *Callistemon viminalis* in the present study.

4 CONCLUSIONS

The survey showed that there was higher number of exotic woody species occurring in the city of Gaborone. The exotic plants could either be introduced by human being or occurring naturally. The high numbers of exotic woody species have changed the landscape of Gaborone as they now dominate the area. Therefore appropriate control measures need to be taken by relevant authorities to control their spread before they outcompete and displace indigenous trees species.

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Table 1 List of exotic plants observed within the surveyed areas

Family names	Scientific names	Abbreviations	Common names
Meliaceae	*Melia azedarach*	MLA	Syringe tree
Meliaceae	*Xylocarpus granatum*	XCG	Mangrove Mahogany
Leguminosae	*Bauhinia variegate*	BHV	Orchid tree
Leguminosae	*Delonix regia*	DLR	Flamboyant tree
Leguminosae	*Cassia corymbosa*	CSC	Cassia
Leguminosae	*Leucaena leucocephala*	LCL	Leucaena
Leguminosae	*Tipuana tipu*	TPT	Tipu
Bignoniaceae	*Tecoma stans*	SLS	Yellow elder
Bignoniaceae	*Jacaranda mimosifolia*	JRM	Jacaranda
Agavaceae	*Agave sisalana*	AVS	Sisal
Myrtaceae	*Eucalyptus camaldulensis*	ELC	Red gum
Moraceae	*Morus nigra*	MRN	Mulberry
Moraceae	*Ficus spp*	FCS	Ficus
Moraceae	*Ficus carica*	FCA	Fig
Apocynaceae	*Plumeria acutifolia*	PMA	Frangipani
Apocynaceae	*Thevetia peruviana*	TVP	Yellow oleander
Myrtaceae	*Psidium guajava*	PDG	Guava
Myrtaceae	*Callistemon viminalis*	CSV	Bottlebrush tree
Sterculiaceae	*Brachychiton acerifolium*	BHA	Australian flame tree
Proteaceae	*Grevillea robusta*	GVR	Silver oak
Malvaceae	*Hibiscus rosa-siensis*	HBR	Hibiscus
Nerium	*Nerium oleander*	NRO	Oleander
Nyctaginaceae	*Bougainvillea spp*	BVS	Bougainvillea
Polygonaceae	*Antigonon leptopus*	AGL	Coral creeper
Musaceae	*Musa acuminate*	MSA	Banana
Cupressaceae	*Widdringtonia nodiflora*	WTN	Mountain cypress
Sapindaceae	*Dodonea viscosa*	DDV	Sand olive
Moringaceae	*Moringa ovalifolia*	MNO	Phantom tree
Anacardiaceae	*Schinus molle*	SNM	Pepper tree
Anarcardiaceae	*Magnifera indica*	MFI	Mango
Rutaceae	*Citrus spp*	CRS	Citrus
Caricaceae	*Carica papaya*	CCP	Pawpaw
Palmae	*Chamaerops humilis*	CMH	Mediterranean Fan Palm
Poaceae	*Phragmites australis*	PGA	Reed

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Poaceae	*Phragmites mauritianus*	PGM	Reed
Cactaceae	*Opuntia ficus-indica*	ONF	Prickly pear
Cactaceae	*Cereus peruvianus*	CRP	Giant cactus
Euphorbiaceae	*Euphorbia molli*	EHM	Christ thorn
Rosaceae	*Prunus spp*	PNS	Peaches

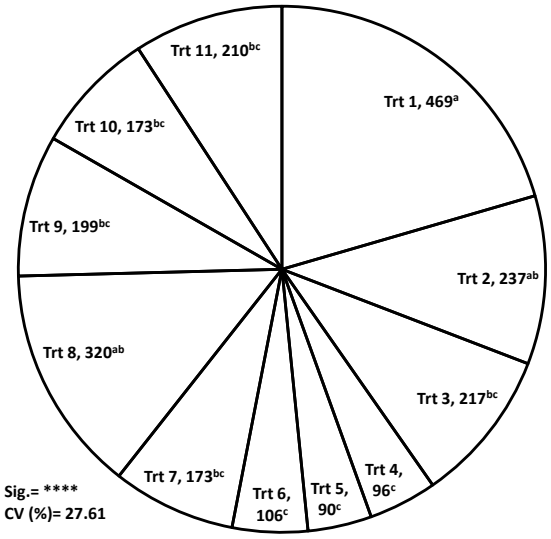

Figure 1. Mean total number of species per treatment
*****Highly significant at p<0.01. Means separated using Tukey's studentized range (HSD) test at p≤0.05, means within sections followed by the same letters are not significantly different. Where, treatment (Trt) is the site*

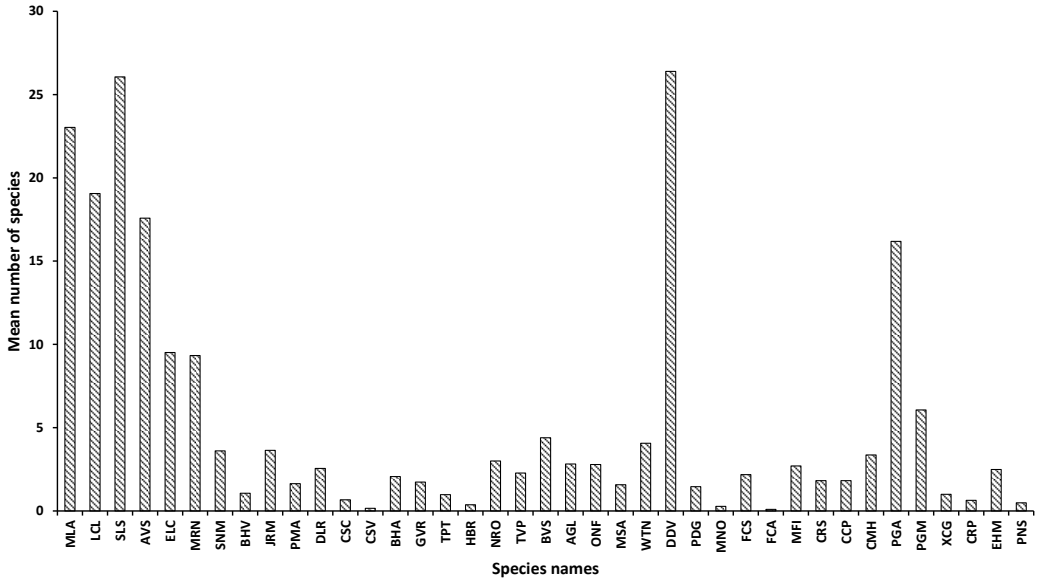

Figure 2. Mean proportion of the total number of recorded individual exotic species