



The casual, naturalised and invasive alien flora of Zimbabwe based on herbarium and literature records

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Dates:

Received: 27 Apr. 2011

Accepted: 18 May 2012

Published: 09 Oct. 2012

How to cite this article:

 Maroyi, A., 2012, 'The casual, naturalised and invasive alien flora of Zimbabwe based on herbarium and literature records', *Koedoe* 54(1), Art. #1054, 6 pages. <http://dx.doi.org/10.4102/koedoe.v54i1.1054>
Note:

 Additional supporting information may be found in the online version of this article as an Online Appendix: <http://dx.doi.org/10.4102/koedoe.v54i1.1054-1>

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Zimbabwe's casual, naturalised and invasive alien plant species were analysed with regard to their habit, origin, mode or purpose of introduction and their invasion status in the country. This alien flora of 391 taxa belonged to 239 genera and 73 families, corresponding to 6.6% of the total flora of Zimbabwe. Of these, 153 (39.1%) plant species were casual aliens, 154 (39.4%) were naturalised and 84 (21.5%) were invasive species. Most invasions in terms of numbers of alien species were in the central and eastern parts of the country. Asteraceae (53 species), Poaceae (48 species) and Fabaceae *sensu lato* (49 species) families were prominent in all the floristic regions of the country. Annual and perennial herbaceous species formed the majority of life forms of the casual, naturalised and invasive alien flora of Zimbabwe. Genera with the highest number of alien species were *Ipomoea* with nine species, *Acacia* and *Euphorbia* with eight species each, *Chenopodium* and *Senna* with seven species each, *Eucalyptus* with six species, *Oenothera*, *Physalis* and *Solanum* with five species each. More than 49.6% of the alien plants in Zimbabwe originated primarily from South, Central and North America, followed by Europe (24.6%), Asia (23.8%), Africa (10.5%) and Australasia (5.9%).

Conservation implications: This research provides baseline information and historical invasion patterns of casual, naturalised and invasive alien flora in Zimbabwe. This inventory is a crucial starting point in trying to understand and initiate the management of biological invasions. This is also important for monitoring new introductions and management of existing alien plants in Zimbabwe.

Introduction

Alien plant species invasions are causing major conservation problems in many regions of the world and are viewed as an important component of human caused global change (Vilà, Meggaro & Weber 1999; Vitousek *et al.* 1997). The spread of alien species is often associated with human activities which include disturbance and fragmentation of the natural environment, urbanisation, agriculture and the use of alien plants for landscaping and erosion control (Vilà *et al.* 1999). The transport of organisms by humans since earliest times and now through increased levels of trade and tourism has led to the widespread breaching of natural biogeographic barriers of alien species (Hulme 2009). According to Vilà *et al.* (1999), there is a need to document naturalised flora before investigating the ecological relationship between invader and invaded habitats. Documentation of alien species and analysing patterns of floristic status, biological attributes and geographical distribution has proved to be a useful approach in understanding alien species richness in various regions (e.g. Khuroo *et al.* 2007; Pyšek, Sádlo & Mandák 2003; Pyšek & Richardson 2006; Rozefelds *et al.* 1999; Stadler *et al.* 2000; Weber, Sun & Li 2008).

Basic information on naturalised plant species, plant invasions and their impacts is lacking in Zimbabwe. Although occasional attention has been paid to alien plants and weeds in Zimbabwe (e.g. Biegel 1977, 1980; Drummond 1975, 1984; Mapaura & Timberlake 2004; Maroyi 2006; Mullin 1996, 2000; Timberlake, Fagg & Barnes 1999; Wild 1955), comprehensive studies on plant invasions are still lacking. The compilation of a catalogue of casual, naturalised and invasive species, hereafter referred to as alien flora, can serve as an initial step towards further detailed studies on the impact of alien plant species on the indigenous flora and fauna. Therefore, the primary objective of this investigation was to provide an overview of the alien species present, and their invasion status and geographical extent in Zimbabwe, based on a literature survey and herbarium records.

Research method and design

Compiling the list

A database of casual, naturalised and invasive alien flora occurring in Zimbabwe was compiled based on a literature survey and herbarium records. All alien plant species ever recorded in



Zimbabwe as escapes from cultivation or naturalised at least once in the wild were included in the database. Species introduced or cultivated without any evidence of having escaped were not considered. Alien species were divided into three categories: casual, naturalised and invasive aliens. According to Pyšek *et al.* (2004), casual aliens reproduce occasionally outside cultivation, do not form self-sustaining populations and rely on repeated introductions for their persistence. Naturalised species are defined as aliens that reproduce consistently without direct human intervention, and invasive aliens as naturalised species producing offspring in large numbers and at considerable distances from the parent plants with the potential to spread over a large area. This definition of invasive alien species used in this study is different from the Convention on Biological Diversity (CBD) Conference of Parties' definition of an invasive alien species, where an alien is defined as a species outside its indigenous geographic range, whose introduction and spread threatens biodiversity (UNEP 2002). The National Herbarium, Harare, Zimbabwe (SRGH), was visited on numerous occasions between 1996 and 2010. Information on herbarium labels, including locality and year of collection of the plant species, was examined and recorded.

Species data

For each taxon, information on its life history traits, such as habit, origin, year when plant species was first collected, mode or purpose of introduction and its invasion status in Zimbabwe were extracted from literature and herbarium records. Economic uses were included and whether the introduction was accidental or intentional. A taxon was allocated to more than one use category if different uses applied to it. A wide range of published literature and websites was consulted (see Online Appendix). The correct identities and names of all the taxa listed were checked and, where names have changed, the currently accepted name was applied. The species nomenclature and classification generally follow Glen (2002). Infra-specific taxa up to the variety level have been recognised. Author citation abbreviations follow those given in Brummitt and Powell (1992). Each taxon's distribution in Zimbabwe was indicated by letters showing the floristic divisions used in Flora Zambesiaca (see Pope & Pope 1998): Northern region (N), Western region (W), Central region (C), Eastern region (E) and Southern region (S).

Results

The present study revealed that the casual, naturalised and invasive alien flora of Zimbabwe is comprised of 391 taxa belonging to 239 genera and 73 families, representing 6.6% of the total Zimbabwean flora. Although this checklist is not exhaustive, it provides good baseline data for future work on casual, naturalised and invasive flora of Zimbabwe. Of these, 153 (39.1%) plant species were casual aliens, 154 (39.4%) were naturalised aliens, and 84 (24.5%) were invasive aliens. Pteridophytes were represented by five plant species (1.3%): *Adiantum raddianum* C. Presl. (Pteridaceae),

Azolla filiculoides Lam. (Azollaceae), *Microlepia strigosa* (Thunb.) C. Presl (Dennstaedtiaceae), *Microsorium scandens* (G. Forst.) Tindale (Polypodiaceae) and *Salvinia molesta* D.S. Mitch. (Salviniaceae). All five species were introduced to Zimbabwe as ornamentals (Online Appendix). Gymnosperms were represented by Cupressaceae and Pinaceae families composed of *Callistris calcarata* F. Muell., *Cupressus lusitanica* Mill., *Cupressus torulosa* D. Don, *Pinus elliotii* Engelm., *Pinus patula* Schltdl. and Cham. and *Pinus roxburghii* Sarg.; all introduced to Zimbabwe at the turn of the 19th and 20th centuries, mainly for timber and as ornamentals (Online Appendix). Dicotyledons constituted the majority of alien flora, with 323 species (82.6%), and monocotyledons contributed 58 species (14.8%). A large number of casual, naturalised and invasive alien plant species in Zimbabwe (289, 73.9%) are from 16 families (Table 1). Plant families with the highest number of casual, naturalised and invasive alien plant species were: Asteraceae (53 species), Fabaceae *sensu lato* (49 species), Poaceae (48 species) and Solanaceae (21 species). The genera with the highest number of casual, naturalised and invasive alien plant species were *Ipomoea* with nine species, *Acacia* and *Euphorbia* with eight species each, *Chenopodium* and *Senna* with seven species each, *Eucalyptus* with six species, and *Oenothera*, *Physalis* and *Solanum* with five species each.

The earliest recorded dates of the alien plants in this study are based on herbarium collections (Online Appendix). The oldest collections date back to the late 1800s, with *Nicotiana tabacum* L. collected in 1870, *Populus X canescens* (Aiton) Sm collected in 1874, *C. torulosa* D. Don collected in 1895, *Eucalyptus camaldulensis* Dehnh. collected in 1897 and *C. lusitanica* Mill. collected in 1900. Most of the species were first collected between 1941 and 1960 (Online Appendix). Intensive collection of casual, naturalised and invasive alien plant species occurred between 1921 and 1980 (Figure 1). Nineteen twenty-one to 1940 was a period of relatively slow accumulation of casual, naturalised and invasive alien plant species records, with a total of 72 species (18.4%) collected during this period (Figure 1, Online Appendix). Most casual, naturalised and invasive alien plant species (153 in total,

TABLE 1: Families with the largest number of casual, naturalised and invasive alien species (with more than 5 taxa) in Zimbabwe.

Family	Number of naturalised alien species	%
Asteraceae	53	13.6
Fabaceae <i>sensu lato</i>	49	12.5
Poaceae	48	12.3
Solanaceae	21	5.4
Brassicaceae	15	3.8
Amaranthaceae	14	3.6
Euphorbiaceae	14	3.6
Convolvulaceae	13	3.3
Myrtaceae	11	2.8
Chenopodiaceae	8	2.0
Malvaceae	8	2.0
Polygonaceae	8	2.0
Verbenaceae	8	2.0
Caryophyllaceae	7	1.8
Lamiaceae	7	1.8
Onagraceae	5	1.3

39.1%) were collected between 1941 and 1960 (Figure 1). The accumulation of casual, naturalised and invasive alien plant species slowed and levelled off between 1961 and 1980, resulting in the collection of 83 species (21.2%) (Figure 1).

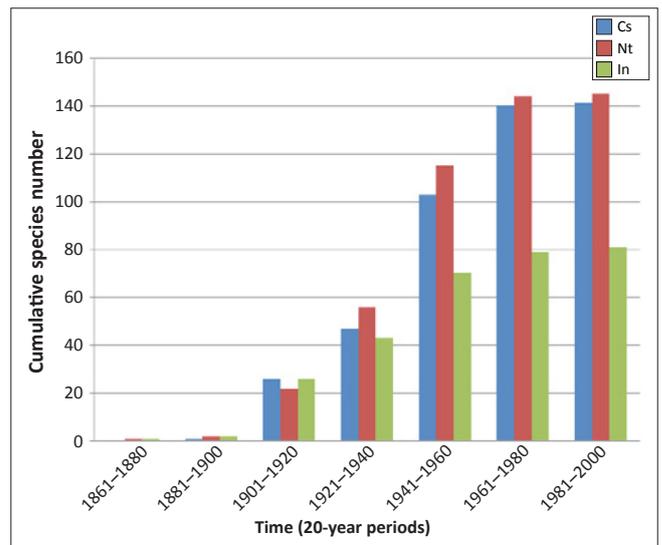
The region with the highest number of casual, naturalised and invasive alien plant species was Central (296, 75.7%), followed by East (279, 71.4%), West (158, 40.4%) and Northern (156, 39.9%) Zimbabwe, whilst Southern Zimbabwe (122, 31.2%) had the lowest number (Figure 2). Most of the species are annual and perennial herbs (Figure 3). More than 49.6% originated primarily from South, Central and North America (Figure 4, Online Appendix), followed by Europe (24.6%), Asia (23.8%), Africa (10.5%) and Australasia (5.9%) (Figure 4). Those plant species that originated from Europe, Asia and Africa are mostly casual aliens (Figure 4).

The alien flora arrived in Zimbabwe through both intentional and unintentional introductions. About 261 species (66.8%) appeared to have been intentionally introduced for various purposes (Table 2). Amongst these were 149 species (38.1%) introduced as ornamentals, 51 species (13%) as food plants, 31 species (7.9%) for fodder, 18 species (4.6%) for timber, six species (1.5%) for fibre, three species each (0.8%) for green manure and medicinal use, and one species (0.3%) as a crop plant (Table 2). In addition, 150 species (38.4%) appear to have arrived in the country unintentionally (Table 2).

Discussion

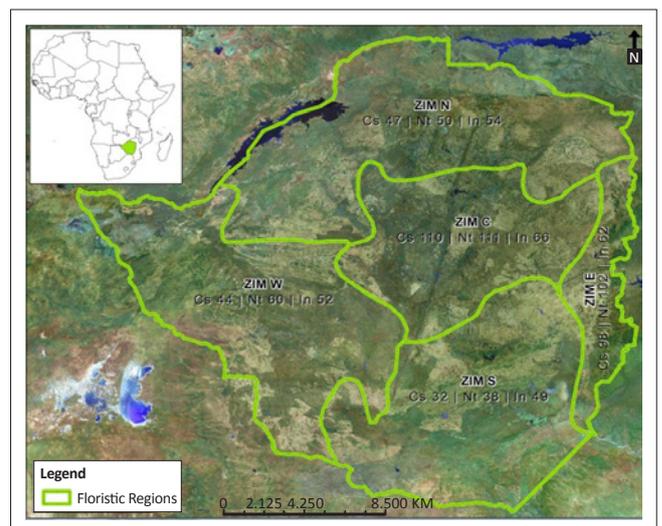
The species list includes a total of 391 casual, naturalised and invasive alien plant species and infraspecific taxa is higher than 328 species listed by Maroyi (2006). The current figure is higher because it utilised herbarium records, an online database (<http://www.zimbabweflora.co.zw/> [Hyde & Wursten 2011]) and published literature (e.g. volumes of *Flora Zambesiaca* and *Kirkia*), unlike findings of Maroyi (2006), which utilised mainly herbarium records. This figure is relatively low when compared with the 5930 indigenous Zimbabwean taxa recorded by Mapaura and Timberlake (2004). This could be a result of under-collection, as plant collectors tend to collect mainly indigenous species, ignoring alien plants (Pyšek *et al.* 2008). The rather small alien flora in Zimbabwe confirms the findings of Foxcroft *et al.* (2010), Le Floch, Le Houerou and Mathez (1990) and Vitousek *et al.* (1997) that African countries generally have few naturalised species compared to the other regions of the world. However, research by McGeoch *et al.* (2010), and Nuñez and Pauchard (2010) showed that the number of documented invasive alien species is underestimated due to lack of information and research.

The taxonomic composition of the alien flora of Zimbabwe is not random and families with the largest number of species belong to the largest families worldwide, for example Asteraceae, Poaceae and Fabaceae. A number of taxa belonging to these families and those of Amaranthaceae, Caryophyllaceae, Chenopodiaceae and Solanaceae have been recorded as weeds of agroecosystems in Zimbabwe



Cs, Casual aliens; Nt, Naturalised aliens; In, Invasive aliens.

FIGURE 1: Cumulative number of species against date of earliest herbarium collection for 391 casual, naturalised and invasive alien plant species in Zimbabwe.



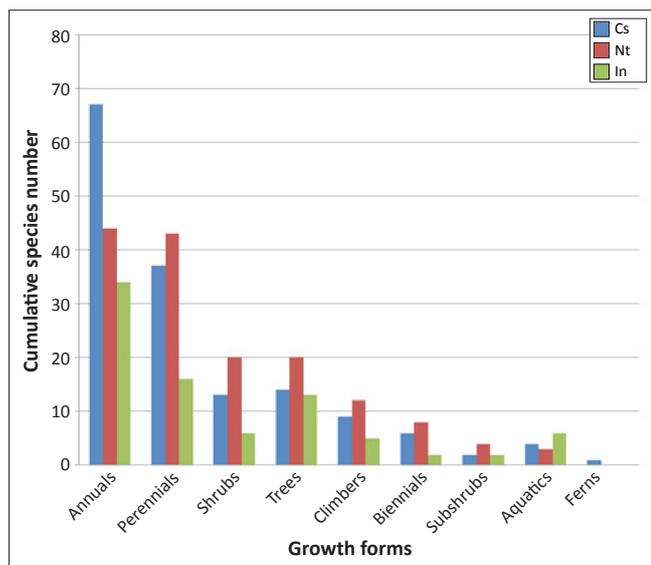
Source: Map modified from Pope, G.V. & Pope, D.G., 1998, *Collecting localities in the Flora Zambesiaca Area*, Flora Zambesiaca Management Committee, Royal Botanic Gardens, Kew, United Kingdom

Cs, Casual aliens; Nt, Naturalised aliens; In, Invasive aliens; N, Northern region; W, Western region; C, Central region; E, Eastern region; S, Southern region.

FIGURE 2: The distribution of the 391 casual, naturalised and invasive alien plant species in Zimbabwe. The numbers in the figure indicate the number of alien species in the five floristic regions of the country.

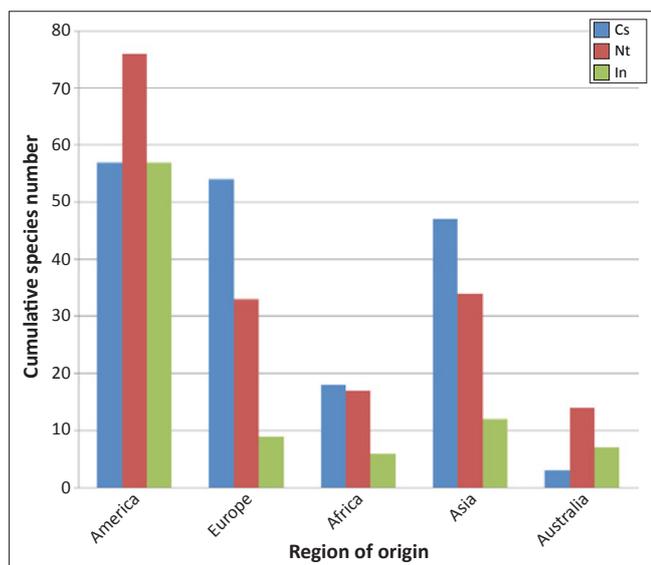
(Drummond 1984; Wild 1955). Heywood (1989) examined the patterns and extent of invasions by agricultural weeds and concluded that most weeds come from the largest plant families like the Asteraceae and Poaceae. Thus, it is also not surprising that annuals and herbaceous perennials are the prevalent life forms amongst the alien flora recorded in this study, as it has been shown in other studies that the herbaceous habit is most frequent amongst the invasive species (Daehler 1998; Kolar & Lodge 2001).

The early phase of exotic plant species introduction involved early settlers who arrived and settled in major towns like Harare and Gweru (Zimbabwe central), Bulawayo



Cs, Casual aliens; Nt, Naturalised aliens; In, Invasive aliens.

FIGURE 3: The growth forms of 391 casual, naturalised and invasive alien plant species recorded in Zimbabwe.



Cs, Casual aliens; Nt, Naturalised aliens; In, Invasive aliens.

FIGURE 4: Regions of origin of alien plant flora in Zimbabwe.

TABLE 2: Possible reasons for the introductions of the alien flora into Zimbabwe. Species may have been allocated to more than one category.

Reason for introduction	Number of species	%
Unintentional	150	38.4
Ornamental	149	38.1
Food	51	13.0
Fodder	31	7.9
Timber	18	4.6
Fibre	6	1.5
Medicine	3	0.8
Green manure	3	0.8
Crop	1	0.3

(Zimbabwe west) and Mutare (Zimbabwe east). Historically, colonists from Europe brought food plants, ornamentals, structural timber species, et cetera, with them during their migration (Maroyi 2006; Mullin 1996). According to Maroyi (2006), small-scale plantings of alien plant species in

Zimbabwe started with European settlement in the 1890s and early 20th century. This was a period when acclimatisation societies and botanical gardens flourished in the British colonies and economic plants were transferred from one continent to another (Maroyi 2006). Over 80% of the alien flora in Zimbabwe originated from America, Europe and Asia. Alien plants were introduced into Zimbabwe from these regions probably through the European colonisers. The relatively lower number of alien species in the southern part of Zimbabwe is due to the harshness of the region's climate. Southern Zimbabwe is hot and dry, characterised by low and erratic rainfall.

The majority of alien plant species recorded in Zimbabwe have been introduced intentionally for economic purposes, although a sizeable proportion of species arrived in the country by accident. Several species of *Eucalyptus* were introduced from Australia for structural timber, furniture, poles, charcoal and medicinal oils (Mullin 1996). About 38.1% of the casual, naturalised and invasive alien plant species in Zimbabwe were introduced into the country as ornamentals. Similar studies in other countries have shown that most invasive plants are ornamentals (Reichard & White 2001). Previous research has shown that whilst many herbaceous ornamentals have been accidentally introduced, woody ornamentals have been almost entirely introduced intentionally, mainly for landscaping (Reichard & White 2001). The accidental introduction of alien plant species into Zimbabwe is also due both to the use of contaminated seeds in agricultural systems and as a result of human transport systems. Nowadays, intensive trade and the constant flow of people have resulted in a large plant transfer, crossing frontiers and geographical boundaries (Del Monte & Aguado 2003).

An understanding of the establishment and distributional changes of alien flora over time is important for making informed decisions in managing existing introductions and predicting future invasions. Although the Zimbabwean alien flora has been noted for some time (Wild 1955), it is only in the last four decades that a profound interest has developed, owing to the important economic impacts of alien weed species on agricultural crops (Drummond 1975, 1984).

The majority of the species (63.2%) considered in this investigation were already casuals, naturalised or invasives in Zimbabwe by 1955, when an initial survey of exotic weeds was carried out (Wild 1955). About 30 alien species were recognised as weeds by Wild (1955). Drummond (1975) reported 45 naturalised woody plant species. Drummond (1984) systematically recorded 62 alien species that grew as weeds in croplands, causing important economic damage in productive lands. The period between 1921 and 1980 was characterised by increased study of the Zimbabwean flora, which boosted awareness and recording of new invaders. Equally intriguing is the fact that the following ten notable introduced species classified as invasive aliens in this study were not documented until the 1960s: *A. filiculoides* (Azollaceae), *Bidens bipinnata* (Asteraceae),



Browallia americana (Solanaceae), *Coreopsis lanceolata* (Asteraceae), *Erigeron karwinskianus* (Asteraceae), *Jacaranda mimosifolia* (Bignoniaceae), *Myriophyllum aquaticum* (Haloragaceae), *Persicaria lapathifolia* (Polygonaceae), *Rubus niveus* (Rosaceae) and *Solanum mauritianum* (Solanaceae).

The number of areas an alien weed species occupies increases with the number of years since the first record of naturalisation. Biological invasions are made up of several stages, which include introduction, naturalisation and spread. Previous research by Binggeli (2001) has shown that there are time-lags between the introductions of exotic plants, their establishment and subsequent spread. It has since been established that only a small proportion of introduced species are capable of spreading and becoming weeds (Kowarik 1995). For example *Acacia mearnsii* (Fabaceae-Mimosoideae), *Cajanus cajan* (Fabaceae-Papilionoideae), *Solanum betaceum* (Solanaceae), *Mangifera indica* (Anacardiaceae), *Nicotiana glauca* (Solanaceae), *Passiflora edulis* (Passifloraceae), *P. patula* (Pinaceae), *Prunus serotina* var. *salicifolia* (Rosaceae) and *Syzygium jambos* (Myrtaceae) were recorded as naturalised only in eastern Zimbabwe by Drummond (1975), but this investigation showed that they are also naturalised in other regions of the country. Information on naturalisation or rate of spread of alien plants increases with more collecting and monitoring efforts. A better understanding of their establishment and distributional changes is important for the development of appropriate alien plant species management plans.

Conclusion

The catalogue of casual, naturalised and invasive alien plant species presented in this study is a critical starting point in trying to understand and initiate the management of biological invasions; and it will serve as a foundation for future research on plant invasions in Zimbabwe. However, the documentation of casual, naturalised and invasive plant species in Zimbabwe is far from sufficient. It is here recommended that extra attention be paid at studying the ecological and socio-economic impacts of introduced plant species on the native communities in Zimbabwe. A better understanding of their establishment, spread, social and economic impacts, and distributional changes over time is vital for making informed decisions on new introductions and managing existing casual, naturalised and invasive alien plant species. Since complete eradication of introduced species is unachievable (Moles *et al.* 2012), there is need to have a historical invasion patterns of alien species and their long-term effects on native communities. This field of study is currently under researched in Zimbabwe and there are few examples where casual, naturalised and invasive alien plant species have been fully evaluated. The result is that, where investigations are done at all, research on such alien plants are often short-term, highly localised, sporadic, largely *ad hoc* and restricted to field studies without underpinning agricultural, scientific or economic studies. Therefore, elucidation of alien plant naturalisation patterns in Zimbabwe will prove crucial in the scientific management of casual, naturalised and invasive alien flora in the country.

Acknowledgements

The head of the National Herbarium and Botanic Garden, Harare, Zimbabwe (SRGH) and staff are thanked for granting access to their facilities, helpful advice and plant identifications. I am also grateful to four anonymous reviewers for constructive comments and Sandra MacFadyen for Figure 2.

Competing interests

The author declares that he has no financial or personal relationship(s) which may have inappropriately influenced him in writing this paper.

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