
DISSERTATION SUBMISSION

Invasive status of pampas grass in South Africa

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Declaration

I, Thembelihle Joyce Mbele, declare that the Master's Degree research dissertation or interrelated, publishable manuscripts/published articles, or coursework Master's Degree mini-dissertation that I herewith submit for the Master's Degree qualification in Botany at the University of the Free State is my independent work, and that I have not previously submitted it for a qualification at another institution of higher education.



Student's Signature

30 October 2024

Date

Department of Plant Sciences

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To God be the glory

List of abbreviations

%:	Percentage
°C:	Degrees Celsius
µl:	Microliter
ANOVA:	Analysis of variance
cm:	Centimetres
CTAB:	Cetyltrimethylammonium bromide
DNA:	Deoxyribonucleic acid
EDTA:	Ethylene-diamine-tetraacetic acid
g:	Gram
IAPs:	Invasive alien plants
ml:	Millilitres
mM:	Millimolar
NaCl:	Sodium chloride
NEM:BA:	National Environmental Management: Biodiversity Act
nm:	nanometer
PCoA:	Principal Coordinates Analysis
PCR:	Polymerase chain reaction
TAE:	Tris-Acetate EDTA
TZ:	Triphenyl tetrazolium chloride
UV:	Ultraviolet

Abstract

Two *Cortaderia* species, *C. jubata* and *C. selloana*, have become invasive outside their native range, including in South Africa. They were introduced to South Africa for ornamental use, erosion control and stabilising mine-dumps. They have long escaped containment and spread throughout the country, invading grasslands, roadsides, wastelands, rivers and seasonally wet habitats. Little is known regarding their distribution, seed viability and whether accurate identifications have been made of the *Cortaderia* species in South Africa, which may hinder effective management. Although the national regulations forbid the trade of pampas grass, the continuing popularity of their inflorescences for home décor and special events is of concern. While nurseries have stopped the sale of the plants, inflorescences are still being sold through retail and informal trade. This study aimed to assess the invasion risk posed by pampas grass in South Africa and distinguish between the different species across their invaded range using molecular techniques. Leaf and seed samples were collected from 79 populations across South Africa. Eight microsatellite primers were used to assess the genetic variation across *Cortaderia* populations. Seed viability and germination success were assessed for seeds from 28 naturalised and 13 traded inflorescences using a triphenyl tetrazolium stain, and germination trials in a growth chamber and greenhouse. Impacts and risks of *C. jubata* and *C. selloana* in South Africa were assessed using version 1.2 Risk Analysis for Alien Taxa (RAAT) framework. Microsatellite confirmed the presence of *C. jubata* and *C. selloana* in South Africa and that *C. selloana* populations have higher genetic diversity compared to *Cortaderia* from other invaded regions. Tetrazolium tests found that *C. selloana* (71.66 %) had higher seed viability than *C. jubata* (54.28 %). Assessments of germination trials in a growth chamber revealed that *C. selloana* (68.89%) had a higher proportion of seeds germinate compared to *C. jubata* (52.62 %) but this difference was not statistically significant. Seed germination under greenhouse experiments also found *C. selloana* (79.15 %) to have higher germination success compared to *C. jubata* (62.54 %). Seed viability of cultivated and naturalised *Cortaderia* inflorescences differed significantly to formally traded inflorescences but not significant to informally traded inflorescences. Seeds from naturalised populations of both *Cortaderia* species had significantly higher germination success (65.69 %, 74.35 %) than the formally

(25.00 %, 5.33 %) and informally traded populations (28.75 %, 35.56 %) under growth chamber and greenhouse experiments, respectively. Viability and germination success of seeds from cultivated *Cortaderia* inflorescences were statistically similar to naturalised inflorescences while those from formally traded inflorescences performed statistically similar to seeds from informally traded inflorescences across triphenyl tetrazolium stain, growth chamber and greenhouse experiments. The risk analysis assessments determined that both *C. jubata* and *C. selloana* have major impacts and a high risk of invasion in South Africa with medium ease of management. Determining the invasion risk posed by pampas grass in South Africa has provided important information on managing these species. Biological control is species-specific; therefore, this study has provided information that will guide the biological control programme of pampas grass in South Africa and future research can focus on finding potential biocontrol agents. Seed viability and germination experiments established that when seeds are present on flowers, most of them are viable and that traded inflorescences' seeds are not sterile and can thus be promoting invasion and further spread of *Cortaderia* species. Effective management of *Cortaderia* species must focus on enforcing legislation to stop this pathway of spread.

Keywords: biological invasions, invasive alien grasses, *Cortaderia*, microsatellites, seed germination, risk analysis

Chapter 1: Introduction to the study

1.1. Introduction

Biological invasions are widely recognised as a major driver of global biodiversity loss (CBD, 2006; Le Roux, 2021) and have the potential to cause significant environmental and socio-economic impacts (Van Wilgen et al., 2001; Pimentel et al., 2005; Zengeya and Wilson, 2020). Many alien plant species in South Africa are already well-naturalised and have substantial environmental and economic impacts, while others are at the early stages of invasion (Nel et al., 2004; Henderson, 2020; Zengeya and Wilson, 2023). Alien plants can change the composition, structure and functioning of ecosystems in many ways (Pysek et al., 2020, 2012; Reynolds et al., 2020; Diagne et al., 2020). Examples include alterations to the structure of vegetation by introducing novel growth forms (Van Wilgen and Richardson, 1985; Brooks et al., 2004; Richardson et al., 2007; Gaertner et al., 2011; Le Roux et al., 2020), and changes to ecosystem processes such as fire regimes (Brooks et al., 2004) and hydrology (Le Maitre et al., 2015). Invasive alien plants (IAPs) can reduce agricultural production, and this results in losses of income (Shackleton et al., 2019; Linders et al., 2021), therefore negatively affecting human well-being.

The first stage of the invasion process is the human-assisted movement of living organisms and/or their propagules from their native or already introduced range across geographical barriers (Blackburn et al., 2011; Le Roux et al., 2020) through many pathways and vectors (Hulme et al., 2008; CBD, 2014; Essl et al., 2015; Faulkner et al., 2020). There is an overall process that accompanies the transition of an alien species from being introduced to becoming invasive (Blackburn et al., 2011; Le Roux et al., 2020). All alien species must overcome a series of barriers such as geography, possibly cultivation, survival, reproduction, dispersal and the environment, to become invasive (Blackburn et al., 2011; Richardson and Pyšek, 2012; Pyšek et al., 2020). Many of these species introduced food, raw materials, for ornamental purposes, erosion control and dune stabilisation (Zengeya et al., 2017; Henderson, 2020; Zengeya and Wilson, 2023). Other alien species have been accidentally introduced and spread across the globe as contaminants or transport stowaways (Hulme et al., 2008; Faulkner et al., 2020). As the human footprint around the globe

increases, so do the alien species either accidentally or intentionally (Richardson and Pyšek, 2006; Hulme, 2009; Blackburn et al., 2019; Faulkner et al., 2020).

Some traits have been identified to be common in many successful plant invasions. For example, Rejmánek and Richardson (1996) found that many invasive alien plants (IAPs) have short juvenile periods and intervals between large seed crops, which results in early and consistent reproduction. They also often produce small, light seeds which are dispersed across long distances and have high germination success (Pyšek and Richardson, 2007; Minor and Gardner, 2011; Moravcová et al., 2015; Barudanović et al., 2021). Invasive alien plants often have a long flowering season, spread vegetatively, and have multiple seed dispersal vectors (Pyšek and Richardson, 2007; Pyšek et al., 2009; Montagnani et al., 2022). Most invasive alien populations contain genotypes with high fitness possessing minimum deleterious alleles (Gaskin et al., 2011; Gaskin 2024). Successful IAPs can also release chemicals that inhibit the growth of surrounding plants as a way of facilitating their population growth and performance (Callaway et al., 2005; Le Roux et al., 2020). All these traits make it unfeasible to control all IAPs (McGeoch et al. 2016). Therefore, decision-makers rely on risk analyses to assess the threats posed and whether and how these species can be managed (Kumschick et al., 2020). Risk analysis provides evidence informed regulation of alien species (Sankaran et al. 2023). In South Africa, the National Environmental Management: Biodiversity Act (NEMBA, Act 10 of 2004) Alien and Invasive Species Regulations (NEM:BA-A&IS regs), list alien species that need to be managed and the Risk Analysis for Alien Taxa (RAAT) framework was developed to provide scientifically based evidence to support the listing (Kumschick et al., 2025).

Grasses are one of the largest plant families, and they have been introduced globally for purposes such as agriculture and horticulture (Reed 2014; Visser et al., 2016). Grasses are highly valued economically as they are the source of the most consumed staple foods in the world, including cereal grains like corn, rice, sorghum and wheat (Weiss et al., 2004; Lopez et al., 2022). Invasive grasses are exceptionally successful travellers, with numerous small, wind-dispersed, persistent seeds that extend their chances of persistence and eventual naturalisation (Milton, 2004; Linder et al., 2018). In their introduced range, they can change the vertical structure of the vegetation and compete with native plants for available resources (Domènech et al.,

2006; Flory and Clay, 2010; Mozdzer et al., 2016) and often increase fuel load and fire intensity (Domènech et al., 2006; Fusco, 2019; Tomat-Kelly et al., 2021). They can also form dense mats that competitively exclude many other herbaceous species (Jacobs et al., 2020).

Cortaderia Stapf is a genus of perennial tussock grasses, mostly from South America (Connor, 1973; Drewitz and DiTomaso, 2004; Testoni and Linder, 2017; Houliston and Goeke, 2017). Two *Cortaderia* species, *C. jubata* (Lemoine) Stapf. and *C. selloana* (Schult. & Schult. f.) Asch. & Graebn. have become invasive outside their native range, particularly in New Zealand, the United States and South Africa (Connor, 1965; Robinson, 1984; Henderson, 2020). Generally, the two species can be told apart by the colour of their flowers, with *C. jubata* having pink to purple flowers while *C. selloana* has white to silver flowers (Stanton and DiTomaso, 2004; Houliston and Goeke, 2017; Henderson, 2020). However, this is not always consistent; hence morphological assessment is not always accurate to distinguish the two species, with both species sometimes displaying white or pink flowers. The primary physiological difference between *C. jubata* and *C. selloana* is their reproductive strategy. *Cortaderia jubata* is apomictic, having only female flowers that are able to set viable seed without fertilisation (Stanton and DiTomaso, 2004). *Cortaderia selloana* reproduces sexually and is functionally dioecious, and can also reproduce asexually by spreading through rhizomes and tillers (Stanton and DiTomaso, 2004).

Cortaderia species (hereafter refers to *C. jubata* and *C. selloana*) are aggressive invaders that can colonise natural and semi-natural habitats (Dellow and McCaffery, 2009; Domènech et al., 2006; Sutton et al., 2021). In South Africa, *Cortaderia* species are often found invading areas along water courses (Henderson, 2020). Once naturalised, they are competitive, restricting the establishment of native plants, and can become a fire hazard due to high biomass and highly flammable leaves (Dellow and McCaffery, 2009). Invasion by *Cortaderia* species reduces grazing capacity and hinders access to certain natural areas by forming dense and impenetrable stands (Blood, 2001; Domènech et al., 2006). *Cortaderia selloana* leaves are sharp with cutting edges while *C. jubata* has abrasive leaves and both can cause superficial cuts to humans and animals (Domènech et al., 2006; Henderson, 2020). *Cortaderia selloana* flowers also produce large amounts of pollen that can cause

allergies (Rodríguez et al., 2021). According to AGIS (2013), in South Africa, the fluffy inflorescences of *C. jubata* cause respiratory problems to humans, especially those suffering from asthma.

Cortaderia species have been reported in all provinces in South Africa (Figure 1.1) and are listed as category 1b species in the National Environmental Management: Biodiversity Act - Alien and Invasive Species Regulations (NEM:BA-A&IS regs, Act no.10 of 2004; revised in 2020), meaning that land occupiers are legally obliged to control them, or to remove and destroy them if possible (Henderson, 2020; Zengeya and Wilson, 2020; Sutton et al., 2021). Their wide distribution may be facilitated by their wide environmental and abiotic tolerances and prolific seed production (Canavan et al., 2019). Management options for *Cortaderia* species are available and are limited to mechanical and chemical control in South Africa.

Mechanical control involves physical removal by uprooting plants and chemical control involves the use of herbicides (DiTomaso, 2000; NSW WeedWise, 2021). However, these management options can be complicated by *Cortaderia* stands often occurring in inaccessible areas and on private property (Henderson, 2020). Furthermore, the species have abundant seed production, positive responses to disturbance, and in some cases, herbicide resistance (Milton, 2004). Biological control (hereafter biocontrol) is a potential management option for *C. jubata* and *C. selloana*. A biocontrol program initiated in New Zealand found two potential biocontrol agents: a floral-smut fungus, *Ustilago quitensis* Lagerh. (Ustilaginales), and a planthopper, *Sacchasydne subandina* Remes Lenicov and Rossi (Hemiptera: Delphacidae) and both of these agents are still under evaluation (Sutton et al., 2021).

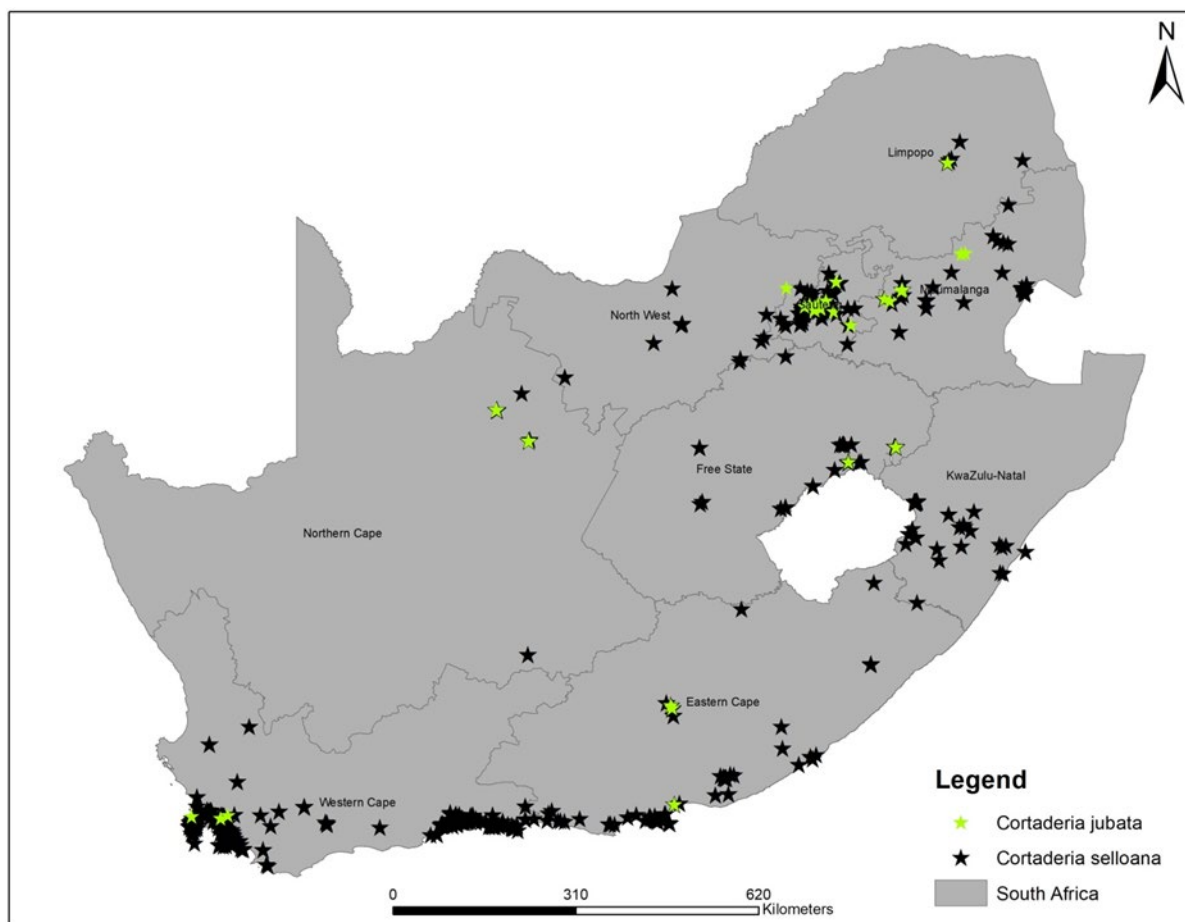


Figure 1.1: Distribution of *Cortaderia* species in South Africa (Data source: iNaturalist, GBIF (<https://doi.org/10.15468/dl.g8bauq>, <https://doi.org/10.15468/dl.4pcrbv>), BRAHMS, Ezemvelo KZN Wildlife and Field data)

1.2. Problem statement and rationale

Invasive alien grasses are known to have many negative impacts on the environment in South Africa (Zengeya and Wilson, 2020). Tall-statured grasses (TSGs) are particularly noted for their ability to dominate plant communities, alter ecosystem function, and suppress the growth of neighbouring plants (Canavan et al., 2019). In South Africa, *Cortaderia* species are becoming more widespread and can invade disturbed and semi-natural areas quickly (Robinson, 1984; Milton, 2004). Up until recently, exemptions were made to allow the trade of sterile cultivars of *Cortaderia* species, which increased the trade and planting of pampas grass over the years (Henderson and Wilson, 2017). However, the updated legislation now forbids the trade of all forms of *Cortaderia* (NEM:BA-A&IS regs, Act no.10 of 2004; revised in 2020).

Despite this, pampas inflorescence popularity is still growing for home decorations and special events (Sutton et al., 2021). Many suppliers claim that they treat or bleach the flowers to sterilise the seeds, which would ultimately prevent the spread of the species (Bloom Space, 2024; Happy Home, 2024); hence the flowers are often sold on the premise that they are sterile. Specific cultivars of *Cortaderia* were developed to be sterile; however, even for cultivars that were planted and stated to be sterile, this may not be the case as cultivar integrity is often not maintained, and it is therefore likely that this trade is fuelling new invasions (Sutton et al., 2021). Currently, *Cortaderia* is present in all provinces, yet there is still limited knowledge of the sterility of these traded plants and those in naturalised populations (Sutton et al., 2021). In addition, while *Cortaderia* species are present in all provinces, risks and threats posed by pampas grass in South Africa have not been formally assessed, and therefore are not known. Manual and chemical control options are available for pampas grasses in South Africa. However, these management interventions are extremely costly and not feasible over large spatial scales. Therefore, more control options such as biocontrol need to be explored for the suppression of *Cortaderia* species. Current distribution databases record two *Cortaderia* species occurring in South Africa, namely *C. jubata* and *C. selloana*; however, given the potential for misidentification through morphological assessment, confirmation of which species occur in naturalised populations is yet to be determined. All these information gaps for *Cortaderia* species in South Africa makes their management difficult, hence, this study will focus on answering and filling in these gaps to help guide their management.

1.3. Aim of this study

- To determine the invasion risk of *Cortaderia jubata* and *C. selloana* in South Africa, through exploring seed viability in traded, cultivated and naturalised populations, confirming the identification of naturalised *Cortaderia* species and to conduct risk assessments of *Cortaderia* species in South Africa. This will help inform future management planning.

1.4. Research questions

- Are *C. jubata* and *C. selloana* the only *Cortaderia* species occurring in South Africa?
- Does the trade of pampas grass in South Africa fuel new invasions by spreading viable seeds?
- What are the risks and threats posed by *Cortaderia* species in South Africa?
- Due to the historical trade of supposedly sterile *Cortaderia* cultivars, has this resulted in some cultivated and naturalised populations having sterile seeds?

1.5. Objectives

- To conduct seed germination trials and lab-based seed viability tests to assess the prevalence of seed sterility in plants sold for flowers and in cultivated and naturalised populations.
- Determine the genetic identity of *Cortaderia* species and assess the genetic diversity of naturalised populations in South Africa.
- Explore the literature on *Cortaderia* species to assess and collate the risks and threats posed by pampas grass in South Africa following the Risk Analysis for Alien Taxa framework.

1.6. Significance of the study

Historically, the horticultural trade of *Cortaderia* species was legally allowed in South Africa under the condition that their seeds were sterile (Department of Environmental Affairs, 2018b). Nevertheless, recently, the trade of these cultivars was recognised as problematic and potentially spreading the species since there was no formal process for verification of *Cortaderia* seeds' sterility in the market (Henderson and Wilson, 2017). Therefore, by conducting seed germination trials obtained from traded flowers, cultivated and naturalised populations, the study sought to determine the prevalence of sterility and, thus establish whether or not this trade is helping spread the species. These results will reinforce the development of management options to prevent the further spread of the species. Genetic analyses of invasive species have been used to identify source populations, the potential to spread, and estimate the number of introduction events that a species may have undergone (Haynes et al.,

2009; Meimberg et al., 2010). A genetic study of *Cortaderia* will confirm which species are present in South Africa and thus, guide a future biocontrol programme. Although both *Cortaderia* species known to be present in South Africa are listed in the NEM:BA regulations, decisions are often made based on limited evidence (Kumschick et al., 2020). Assessing impacts and threats posed by pampas grass in South Africa following the RAAT framework will explicitly highlight uncertainties and determine whether and how these species can be managed in South Africa.

Dissertation layout

Chapter 1 –General introduction of the study, problem statement and rationale and includes the aims, objectives and significance of the study.

Chapter 2 – The literature review of the study.

Chapter 3 – Genetic variation in two widespread *Cortaderia* species in South Africa.

Chapter 4 – Seed germination of cultivated, naturalised and floristically traded *Cortaderia* species in South Africa.

Chapter 5 –General discussion, discusses the results of the risk analyses, conclusion and recommendations of the study.

Annexure A – Province sites where leaf samples were collected across the country.

Annexure B – Towns and suppliers from where *Cortaderia* inflorescences were collected and bought.

Annexure C – Compiled reports of Risk Analyses of *Cortaderia jubata* and *Cortaderia selloana* in South Africa.

Please note: References for Chapter 1 are included in Chapter 5.

Chapter 2: Literature Review

2.1. Invasive alien plants

2.1.1. Invasive alien plants

Van Wilgen et al. (2020) define alien plants as plants present in a site outside their natural range due to human activity that has enabled them to overcome biogeographic barriers. Some alien plants become naturalised and spread rapidly over substantial distances from introduction sites; these species are then defined as being 'invasive'. These invasive alien plants (IAPs) often outcompete native species during the process of colonisation of new environments (Gioria and Osborne, 2014).

2.1.2. Reasons for the introduction of alien plants

Alien plants are intentionally and unintentionally moved around the globe by humans, and their number and impacts have increased for many species (Richardson et al., 2003; Pyšek et al., 2020; Capinha et al., 2023). Alien plants are introduced to new environments for different purposes (Hulme et al., 2008; CBD, 2020; Faulkner et al., 2020). The primary reasons for introducing alien plants are for agriculture, raw materials, ornamental purposes, erosion control, forestry and dune stabilisation (Richardson and Rejmanek, 2011; Zengeya et al., 2017). In addition, the great bulk of human dietary needs in most parts of the world are met by species that have been introduced from elsewhere (McNeely, 2001). For example, some of the world's ubiquitous foods such as potatoes and tomatoes come from plants that were introduced to the rest of the world from the Americas (Keller et al., 2011).

2.1.3. Mechanism of movement – pathways

Pyšek et al. (2011) defined invasion pathways as “a suite of processes that result in the introduction of an alien species from one geographical location to another”, and vectors as “dispersal mechanisms and means of introduction”. There are three general mechanisms through which alien species are introduced and thus enter a new region: movement of a commodity, the arrival of a transport vector, or natural spread (Hulme et al., 2008; Faulkner et al., 2020). These three broad mechanisms can be further

broken down into six major pathways: release, escape, contaminant, stowaway, corridor, and unaided expansion (CBD, 2020; Figure 2.1).

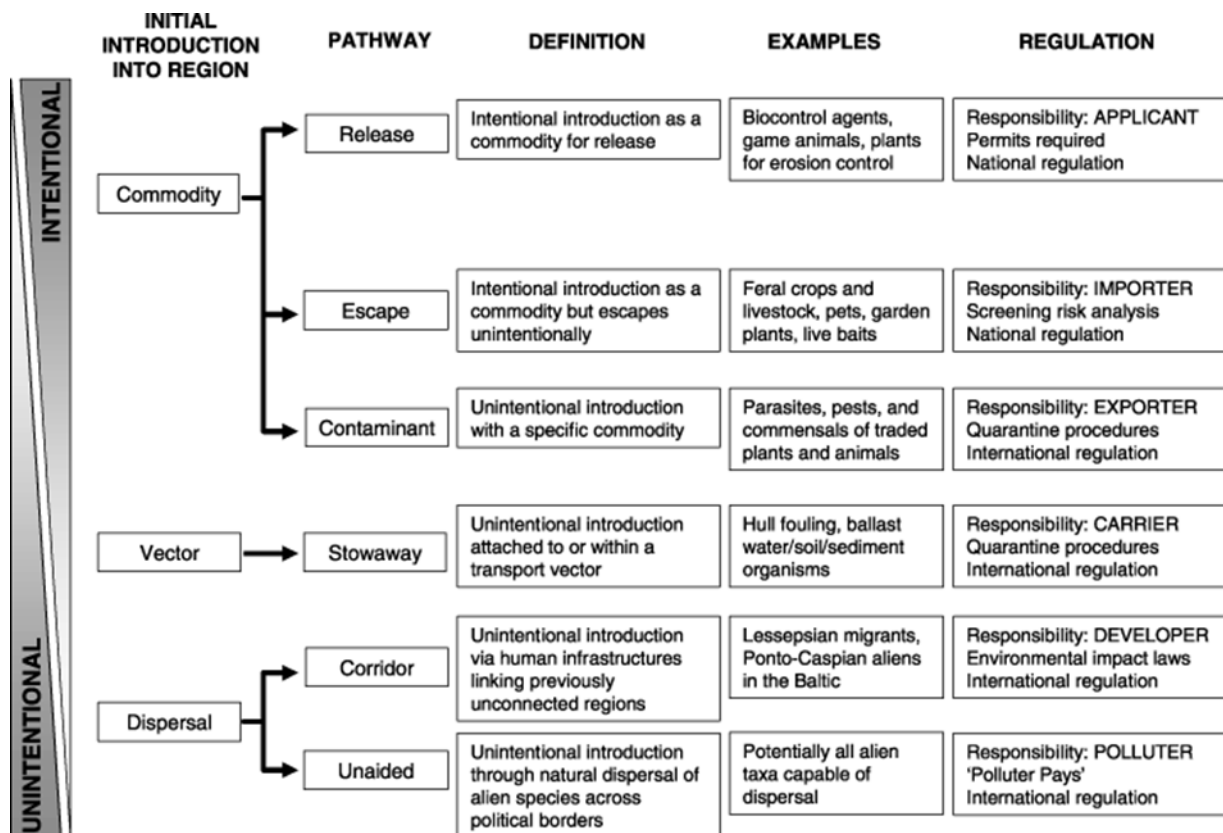


Figure 2.1: A simplified framework of the mechanisms and categorisation pathways of the initial introduction of alien species into a new region (Figure taken from Hulme et al., 2008).

2.1.4. Introduction and naturalisation of alien plants

To become invasive, a species must pass through several transitions (Blackburn et al., 2011; 2014; Figure 2.2). Firstly, it must successfully pass the introductory pathway and survive transit (Faulkner et al., 2020). When it arrives in a region beyond its native range or introduced from an adventive range due to direct or indirect human intervention, it is referred to as “introduced” (Keller et al., 2011). Once introduced, a species then faces the barrier of being able to survive and grow in the new environment (Richardson et al., 2000; Blackburn et al., 2011). Once a species survives, escapes, and begins to reproduce without direct human intervention, it is referred to as being “naturalised” (Keller et al., 2011). Once a species has successfully

overcome geographic, environmental, and reproductive barriers, there is a period of rapid population growth and the taxon can be declared as successfully naturalised because at this stage populations are sufficiently large that the probability of the population dying due to environmental stochasticity is low (Richardson et al., 2000; Larkin, 2012). Once the species has successfully naturalised, the species then begins to spread, which is the final stage of the invasion process.

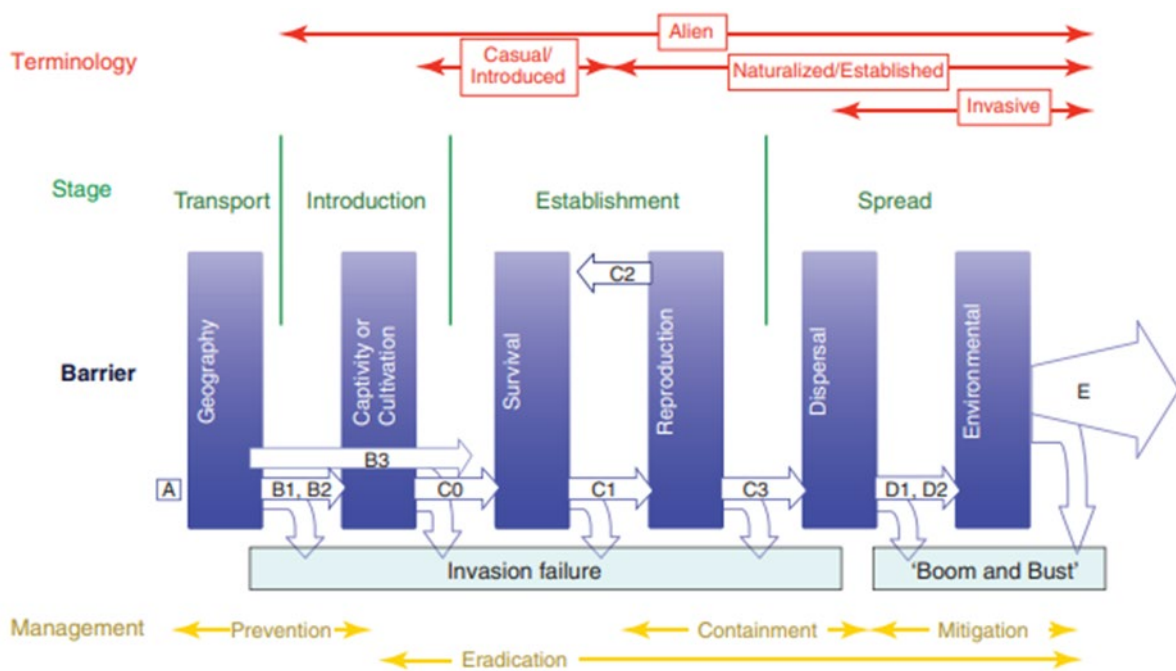


Figure 2.2: The proposed framework that recognises the invasion process, showing that it can be divided into a series of stages, and that in each stage there are barriers (represented by A-D) that need to be overcome for a species or population to pass on to the next stage (Figure taken from Blackburn et al., 2011).

2.1.5. Negative impacts of invasive alien plants in South Africa

Invasive alien plants are a growing concern and accountable for tremendous negative impacts on the environment in South Africa (Zengeya and Wilson, 2020). For example, biological invasions are the third largest and ongoing threat to South Africa's biodiversity and are estimated to account for 25% of all biodiversity loss (Zengeya and Wilson, 2020). Invasive alien plants are the most diverse, widespread, and damaging group of invaders in the country (Van Wilgen et al., 2004; Zengeya and Wilson, 2020).

They can transform ecosystems by, for example, using excessive amounts of resources (notably water), adding resources (nitrogen), accumulating litter, and promoting or suppressing fire (Richardson and Van Wilgen, 2004). These changes alter the flow and availability of nutrient resources. For example, Australian *Acacia* species (*A. cyclops* A. Cunn. Ex G. Don and *A. saligna* (Labil.) H.L. Wendl.) have altered nutrient cycling regimes in the fynbos' nutrient-poor systems due to their ability to fix atmospheric nitrogen (Van Wilgen et al., 2001a). Dense stands of alien trees and shrubs in the fynbos can rapidly reduce the abundance and diversity of native plants (Richardson and Van Wilgen, 2004). Invasive alien plants can reduce both surface water runoff and groundwater recharge, increasing the risk and intensity of wildfires (Gorgens and Van Wilgen, 2004). Every year, it is estimated that 1,44 billion m³ of water is lost to invasive plants in South Africa and this water loss is enough to provide 3,38 million households of four inhabitants with water for a year (Steyn et al., 2019). As wildfires become more intense and burn at higher temperatures, water-repellent layers are generated in the soil, leading to an increase in soil erosion (Smith et al., 2011).

Invasive alien plants also negatively impact the economy (Van Wilgen et al., 2001a). Biodiversity has significant economic benefits such as providing grazing, harvesting of natural products, recreation, and nature-based tourism. Harvesting and recreational use values are reduced when pristine areas become densely invaded by alien plants (Turpie and Heydendrych, 2000). Invasive alien plants may be using as much as 6.7 % of the country's water runoff (Department of Environmental Affairs, 2018a). Water is a limited resource in South Africa and water loss will restrict the potential for economic growth (Van Wilgen et al., 2001a). Plant invasions have been estimated to have reduced the value of fynbos ecosystems by over ZAR 21 trillion (Van Wilgen et al., 2001a; 2012). An estimated ZAR 600 million is spent annually to clear IAPs in over 10 million hectares of land in South Africa (Department of Environmental Affairs, 2018a). An amount of ZAR 9.6 billion has been spent managing biological invasions in South Africa between 1960 and 2023 (McCulloch et al., 2024). This amount represents only 4 % of the ZAR 231.8 billion predicted as being needed to manage IAPs over the same period (McCulloch-Jones et al., 2024).

Invasive alien plants negatively impact human livelihoods and health (Mazza et al., 2014; Shackleton et al., 2019). For example, *Opuntia aurantiaca* Lindley causes

injury due to sharp thorns (McGarry et al., 2005) and provokes allergies (Domènech et al., 2006). Invasive alien plants can decrease the supply of natural resources used by households and reduce agricultural production (livestock and crops) which can result in losses of income and increased vulnerability (Shackleton et al., 2019). According to McCulloch-Jones et al. (2024), the cost of damage caused by invasions far exceeds expenditure on control.

2.1.6. Management of invasive alien plants

It has been recommended that the first effective step in managing IAPs is preventing species' entry at the border (Pyšek et al., 2020). Many countries have adopted either a list of regulated species based on risk assessments, banning the importation of high-risk species (Mgidi et al., 2007; Genovesi et al., 2015), or a white-list approach, whereby planned introductions of all alien species are prohibited unless they are explicitly determined to be low-risk (McNeely, 2000; Pyšek et al., 2020). Ideally, no alien species should enter a country without going through an appropriate risk assessment process, following established environmental impact assessment procedures (Mgidi et al., 2007). In South Africa, there is legislation that regulates the intentional keeping, breeding, cultivating, transporting, placing on the market, and importing of alien species (Zengeya and Wilson, 2020; 2023). This legislation which guides the management of alien species in South Africa is the National Environmental Management: Biodiversity Act (NEM:BA, Act 10 of 2004) and the Alien and Invasive Species Regulations (hereafter called NEM:BA).

For an alien species to be regulated in the NEM:BA regulations, a formal assessment of the risks and threats posed by the species needs to be carried out using the Risk Analysis for Alien Taxa (RAAT) framework. The framework outlines a series of questions related to the likelihood of invasion, spread, potential impacts, and options for management (Kumschick et al., 2020). The framework involves collating relevant data from published literature to support a transparent process to the listing of alien taxa under NEM:BA (Kumschick et al., 2020). It also provides a defensible process for developing recommendations for the management of the assessed taxa. Once the risk assessment is complete, it is then sent to the Alien Species Risk Analysis Review Panel (ASRARP). The ASRARP is an independent scientific advisory panel,

hosted by the South African National Biodiversity Institute (SANBI) on behalf of the Department of Forestry, Fisheries and the Environment (DFFE), that reviews risk analyses for alien taxa, particularly concerning potential imports and listings, and assists in reviewing guidelines for risk analyses and changes to the A&IS Regulations (Wilson and Kumschick, 2024). Once the ASRARP approves a risk analysis, they make a recommendation to DFFE. The DFFE then make a final decision on the taxon's NEM:BA listing.

Once an IAP is introduced, mitigation, which includes eradication, containment, and control, is an option for managing the species (Richardson et al., 2003; Zengeya et al., 2017). A critical first step in a mitigation programme is determining the management goal. For example, is the intention to eradicate the IAP, or to reduce it to a certain level? If the latter, to which level will it be reduced, and how will it be maintained at such a level? Eradicating the entire population of an alien plant within a managed area is often the most desirable outcome and has proven to be feasible in some situations (Jones et al., 2016; Torres et al., 2018). Where eradication is not possible, containment may be an appropriate strategy to limit the spread in places where the range of the invasive species is limited (McNeely, 2000). Regular monitoring outside the control boundaries is essential, with quick action to eradicate any new outbreaks.

Once invasive alien populations are expansive, they can no longer be contained or eradicated; measures must be taken to control them from spreading further (Mgidi et al., 2007). Control refers to reducing the impacts and population sizes of the IAP to an acceptable threshold (McNeely, 2000). Management options include mechanical, chemical, or biological control (Van Wilgen et al., 2001b). Therefore, policies and strategies are developed and implemented for the long-term management of IAPs (Bomford and O'Brien, 1995; Pyšek et al., 2020; Robertson et al., 2020). The management objective should specify the geographic areas of concern, in priority order. Once the objective has been agreed upon among all interested parties, a plan needs to be put in action for achieving the objective, involving research, surveys, identification of control options, implementation, monitoring, and follow-up (McNeely, 2000).

2.1.7. Use of molecular ecology in invasion biology

Understanding genetic characteristics of successful invaders and their invasion pathway is important for the management of alien species and development of policy and legislation (Canavan et al., 2017; Houlston and Goeke, 2017; Freeland, 2020; Canavan et al., 2022). Biological invasion is a multi-step process which involves population, community, evolutionary and physiological biology during the various stages of invasion (Rowe et al., 2017). There are specific molecular tools that can be used to investigate biological invasions (Blanchet, 2012; Rowe et al., 2017; Freeland, 2020).

Molecular tools can also be used to identify sources of invaders and pathways of invasion by quantifying genetic relationships between source and invaded populations (Estoup and Guillemaud, 2010; Canavan et al., 2017). For example, a study by Canavan et al. (2017) used genetics to explore the origin and genetic diversity of the giant reed, *Arundo donax* L., in South Africa and found that *A. donax* in South Africa shares the same haplotype (haplotype M1) as many other invasive populations globally; a lineage that is believed to originate in the Indus Valley in Asia (Ahmad et al., 2008).

Understanding why some species succeed in naturalising new populations in the introduced range while others fail is a major objective in invasion biology. Biological characteristics have been used to explain invasion success of many species (Gioria et al., 2023). However, the ability to invade new environments can differ among species (Kelly et al., 2006; Garnas et al., 2016), and genetic variability is an important factor of the population's ability to invade a new environment (Roman and Darling, 2007; Houlston and Goeke, 2017). Molecular tools can be used to determine whether the naturalised population has lost genetic diversity during the invasion or not (Houlston and Goeke, 2017; Canavan et al., 2017). According to Simon et al. (2011), most invasive populations of topmouth gudgeon, *Pseudorasbora parva* (Temminck and Schlegel), have a higher genetic diversity (mitochondrial genes) than native, source populations due to multiple invasions of a single European location by several source populations (Simon et al., 2011). In contrast, a study by Kawamura et al. (2010) on genetic traits of bluegill sunfish, *Lepomis macrochirus* Rafinesque, populations in Japan using microsatellite markers showed that few individuals have been imported

to a single location from which they subsequently dispersed throughout the country (Kawamura et al., 2010). Most of these naturalised populations showed a relatively low level of genetic diversity compared to the source population (Kawamura et al., 2010). The *P. parva* example illustrates a case where genetic admixture may have increased the genetic diversity of the invading population, hence its invasive potential, while the *L. macrochirus* example suggests that this successful establishment pattern cannot be applied to all invaders (Blanchet, 2012).

Most alien species that invade new environments are well described phenotypically (Blanchet, 2012). However, there are many other species whose morphological identification is difficult to ascertain from congeneric species and they are referred to as cryptic species. Cryptic species can be introduced without human recognition of their genetic and ecological uniqueness, leading to a cryptic invasion (Miura, 2007; Garnas et al., 2016). Cryptic invasions can be successfully monitored using molecular markers as they are genetically unique. For example, genetic monitoring of commensal rodents in South Africa uncovered the presence of *Rattus tanezumi*, a South-East Asian endemic which was not previously known to occur in Africa (Bastos et al., 2011).

2.1.8. Importance of conducting seed germination trials in invasion biology

Conducting seed germination trials of IAPs is important to understand their invasion success (Gioria et al., 2018). Germination percentage and timing are key traits that play an important role in biological invasions (Zhang et al., 2011). Plants with certain traits, such as fast and profuse germination, fast growth, and high reproductive ability, are more likely to become invasive when introduced to new environments (Van Kleunen et al., 2016). For example, a study by Guido et al. (2017) performed a short-term germination experiment to explore some mechanisms that may explain the success of *Eragrostis plana* Ness invasion in southern Brazil and compared the germination rate with eight common native grasses. The germination rate of *E. plana* was remarkably high, reaching 73.3% within 24 hours. This early germination explained its high invasion potential, as immediate access to limited resources enhances opportunities for establishment and growth (Guido et al., 2017;

Gioria et al., 2018). Understanding invasion success of alien plants and traits that make them successful, helps guide their management.

2.2. Invasive alien grasses

2.2.1. The Poaceae family

The Poaceae family is among the most important families of angiosperms regarding morphological diversity, ecology, and economic importance (Ceccoli et al., 2015). It comprises over 12 000 wind-pollinated species. It is classified into 771 grass genera belonging to 12 subfamilies (Anomochlooideae, Aristidoideae, Arundinoideae, Bambusoideae, Chloridoideae, Danthonioideae, Micraioideae, Oryzoideae, Panicoideae, Pharoideae, Pooideae and Puelioideae) all over the world (Clark et al., 1995; Garcia-Mozo, 2017). Poaceae species are annual or biannual grasses with hollow stems. Young leaves grow from the base of the plant, rather than the tip (Garcia-Mozo, 2017). The Poaceae family includes several major crop species (barley, maize, oats, rice, rye, wheat, etc.) that directly contribute to 60% of human food consumption and indirectly to about 20% of the world's carbohydrate diet (Hamzeh'ee and Jalili, 2018). Besides crops, thousands of Poaceae species are of considerable ecological importance, covering the land surface of most biomes worldwide (Garcia-Mozo, 2017), and providing important services such as water catchments, biodiversity reserves and serving as carbon sinks to alleviate greenhouse gas emissions (Boval and Dixon, 2012). Poaceae species also play a huge and important role in providing grazing or feed for animals (Boval and Dixon, 2012).

2.2.2. Characteristics of invasive alien grasses

Invasive species are known to possess strong functional traits that allow them to proliferate well in their recipient environment (Richardson and Pyšek, 2012; Gallien and Carboni, 2016). For alien plant species to be invasive, there are several attributes that they often display, such as high reproduction rates, rapid growth and highly viable seeds (Rejmanek and Richardson, 1996). Invasive alien grasses can sometimes alter stream hydrology. For example, in South Africa, they pose a threat to water security

for South Africa's growing human population by forming dense stands along riverbanks (Milton, 2004).

Alien grasses often have short juvenile periods, allowing them to reproduce continuously throughout the growing season, resulting in rapid population growth (Rejmanek and Richardson, 1996). They also have a small seed mass, which enables the abundant seeds to be easily dispersed (Rejmanek and Richardson, 1996).

2.2.3. *Alien grasses in South Africa*

The first alien grasses introduced into South Africa were crops, such as the millet grasses, *Eleusine coracana* (L.) Gaertn, *Pennisetum glaucum* (L.) R.Br., and *Sorghum bicolor* (L.) Moench (Antonites and Antonites, 2014). Alien grasses in South Africa were also commonly imported for forage, horticulture, soil stabilisation, food, beverages, and as raw materials (Visser et al., 2017). Visser et al. (2017) updated a review that was compiled by Milton (2004) and found that a total of 256 alien grass species has been introduced into South Africa and 122 of them have naturalised. Visser et al. (2017) found that most grasses in South Africa are of Eurasian origin, and the greatest number of alien grass species is in the south-west of the country. In South Africa, 37 alien grasses are identified as invasive (Visser et al., 2017). Two grasses, *Cortaderia selloana* (Schult. & Schult. f.) Asch. & Graebn. and *Arundo donax* L., were found to have major to massive impacts (Zengeya and Wilson, 2020). Management options for the 37 invasive grasses were explored, with only 11 of those species having management information available (Visser et al., 2017). Before 2004, only nine grass species were legislated for management, and 33 species were prohibited from being introduced (Milton, 2004). Currently, fourteen grass species are legislated (NEM:BA-A&S regs, Act no.10 of 2004; revised in 2020).

2.3. **Tall-statured grasses**

According to Canavan (2018), of the more than 11,000 species of grass globally, 929 (about 8.6%) grow more than two meters tall, and these species have been termed tall-statured grasses (TSGs) (Figure 2.3). Tall-statured grasses can be considered a functional group as they have similar invasion syndromes when they establish in non-native ranges, including competitive traits associated with fast growth, high biomass

production, and impacts on ecosystems (Lambert et al., 2010; Saltonstall et al., 2010; Pagad, 2016; Canavan et al., 2018, 2019). Many TSGs, such as *Arundo donax* L., *Miscanthus x giganteus* Greef and Deuter, *Panicum virgatum* L., *Phalaris arundinacea* L. and *Phragmites australis* Cav. (Trin.) ex Steud., are a promising source of renewable energy (Lambertini, 2019). They occur in grasslands, riparian areas and estuaries, as well as tropical and temperate forests, yet the abiotic and biotic impacts are often similar across ecosystems. They are useful to humans for food, as ornamentals, biofuels and other uses (Canavan et al., 2019). Many studies have recognised the benefits of increased height for initial colonisation by alien plants, as it is associated with better light capture and competitive ability (Pyšek et al., 2012; Moodley et al., 2013). Increased height also contributes to specific environmental impacts such as reduction in light availability, changes to fire regimes, and alteration of nutrient cycles (D'Antonio and Vitousek, 1992; Meyerson et al., 1999; Smith et al., 2013; Visser et al., 2016). In South Africa, two TSGs from the *Cortaderia* genus have been reported to occur and are widely distributed across the country.

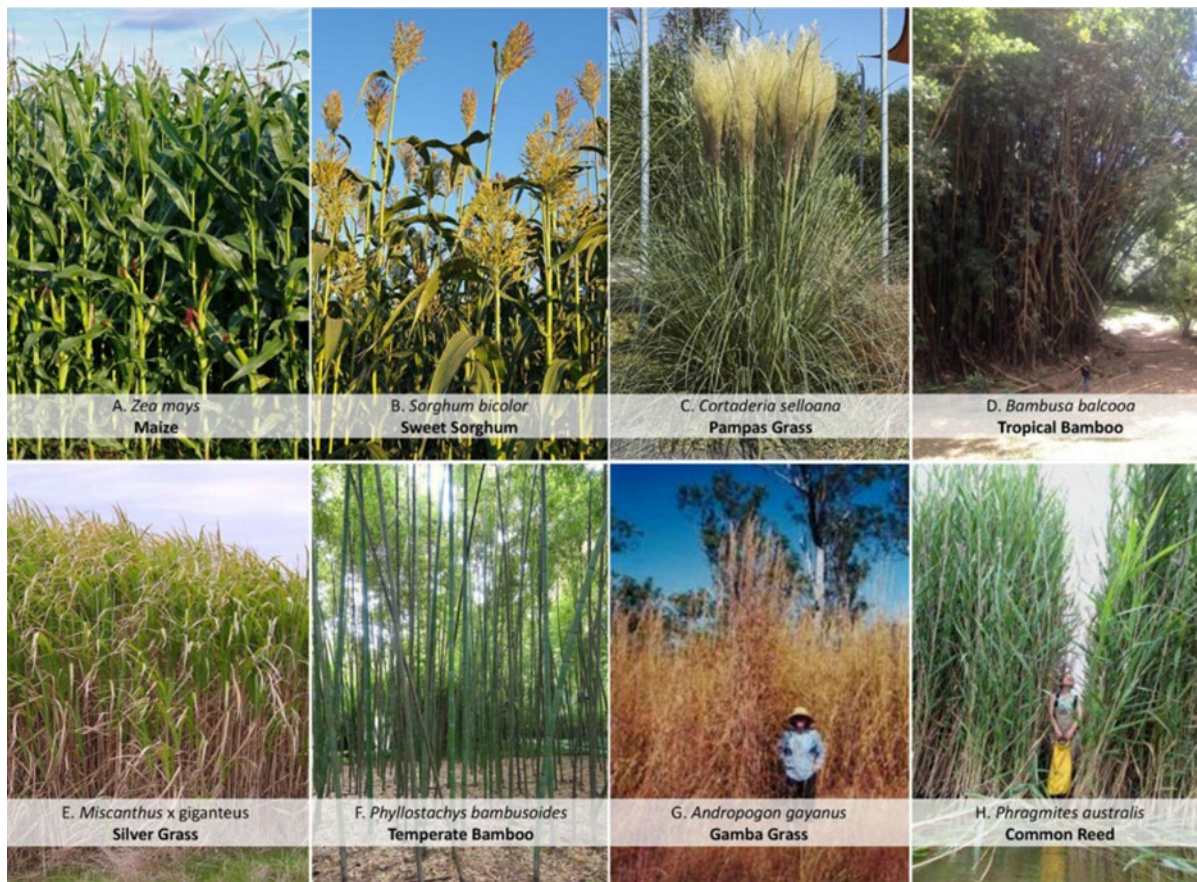


Figure 2.3: Tall-statured grasses in a range of different ecosystems, being used for different purposes (Figure taken from Canavan et al., 2019).

2.4. *Cortaderia* species

2.4.1. Geographic distribution

The genus *Cortaderia* is comprised of 24 species of perennial tussock grasses, mostly from South America (Connor, 1973; Drewitz and DiTomaso, 2004; Houliston and Goeke, 2017). The large, exerted plumes of species such as *C. jubata* (Lemoine) Stapf and *C. selloana* (Schultes) Asch. & Graebner make them attractive as garden plants and they have become cultivated globally (Lambrinos, 2001; Figure 2.4). Both species are present in Australia, Europe and North America, having been introduced in the middle of the 19th century (Lambrinos, 2001). They have since escaped from private and public gardens or urban parks and are now naturalised in New Zealand (Connor, 1965; Edgar et al., 1991), South Africa (Robinson, 1984), and the Hawaiian Islands (Chimera, 1997). They have extensively spread in Europe, particularly in

France, Italy, Portugal (Galasso et al., 2018, Ries and Pagad, 2020), Spain (Cires et al., 2022), the United Kingdom and Turkey (Tanner et al., 2017; Tarabon et al., 2018).



Figure 2.4: (A) *Cortaderia selloana* occurring in the Free State Province, and (B) *Cortaderia jubata* found in Gauteng Province; both planted as ornamentals (photo credit: Thembelihle Mbele).

2.4.2. *The biology of Cortaderia species*

Gynodioecism is the breeding system employed by most *Cortaderia* species. Gynodioecism is an outbreeding system of interbreeding females and hermaphrodites, although hermaphrodites may often be self-compatible as well (Beuzenberg and Beuzenberg, 1965; Connor, 1973). In populations occurring in the wild, gynodioecious species consist of plants of two sex forms; in one, all flowers are functionally hermaphrodite, and in the other, all flowers are functionally female through the presence of male sterility (Beuzenberg and Beuzenberg, 1965; Connor, 1973). Flowers of hermaphrodite plants of *Cortaderia* species are characterised by large pollen-filled anthers and small gynoecia; while those of female plants possess flat,

white, or transparent, sterile anthers and larger gynoecia. Both sex forms set seeds (Connor, 1973), however, only about 10% of seeds from hermaphrodite plants are viable for *C. selloana* compared to over 90% of seeds from female plants (Domènech, 2005).

One of the most evident characteristics of *Cortaderia* species associated with gynodioecism is flowering behaviour. Panicles of hermaphrodite plants begin emergence and anthesis earlier in the season (usually 5-10 days) than those of female plants (Connor, 1979). Inter- and intra-plant pollination occurs among hermaphrodites, resulting in seed set (Connor, 1973; Connor and Charlesworth, 1989). There is sufficient overlap for the cross-pollination of the later-flowering females. Seasonal earliness or lateness of flowering is maternally controlled in *C. selloana*. Only at the very earliest stages in floral development is it impossible to determine the sex form of a *C. selloana* plant (Connor, 1973). Female plants of *C. selloana* have significantly more florets per spikelet than hermaphrodites and panicles of hermaphrodites are more fragile than those of female plants (Connor and Charlesworth, 1989).

At maturity, seed-bearing female florets of *C. selloana* are readily wind-borne, and distribution can be effective over some distance (Connor, 1973; DiTomaso et al., 2010). Winds need not be strong to be effective in dispersal, as slight up-draughts can raise the florets (Connor, 1983). Seed-bearing florets from hermaphrodites, however, tend to fall directly to the ground, and dispersal is very restricted except in the strongest winds. In *C. jubata*, where only females occur and produce seeds from diploid cells without meiosis and fertilisation (Rieseberg and Noyes, 1998; Hand and Koltunow, 2014), wind dispersal is as efficient as in *C. selloana* (Connor, 1973). Female plants of both these species bear abundant long hairs on the ovary, while those of hermaphrodites are glabrous or only slightly hairy (Connor, 1973). These hairs cover the tiny flowers, making the plumes of female plants broad and full and much more visible than the plumes of hermaphrodite plants, which lack hairs on their flowers.

Cortaderia seeds germinate under a wide range of environmental conditions (Domènech and Vilà, 2008). Although *C. jubata* and *C. selloana* are morphologically similar (Lambrinos, 2002), their seed germination conditions can differ. The germination rate of *C. selloana* increases under shaded conditions, which is the opposite of *C. jubata* which has increased germination under light (Drewitz and

DiTomaso, 2004; Domènech and Vilà, 2008). Both species have optimal seed germination rates at 20-25 °C and high-water availability (Drewitz and DiTomaso, 2004; Bacchetta et al., 2010), but *C. selloana* has higher seed germination than *C. jubata* (Lambrinos, 2002). *Cortaderia jubata* seeds that are below 0.2 mg in weight do not germinate while those over 0.5 mg in weight have high germination success (90 %) (Drewitz and DiTomaso, 2004).

Genetic engineering has been used to create male- and female-sterile crops of various economically important grass species (Bucciaglia et al., 2003; Dotson, et al., 1996). There are many flowering herbaceous crop candidates for transformation into sterile cultivars and these include *C. jubata* and *C. selloana* (Anderson, 2007). Dana (2002) outlined the development of sterile cultivars as one possible way to utilize alien grasses while protecting the native biodiversity. Therefore, researchers have been trying to produce sterile cultivars of alien plants to limit the spread and environmental problems caused by their invasions (Freyre et al., 2016; Bechtloff et al., 2019). However, there are still challenges with proving that the seeds are indeed sterile as some plants which were deemed to be sterile have been shown to not be sterile (Anderson and Ascher, 1993; Li et al., 2004). Previous exemptions in NEM:BA allowed for trade of sterile cultivars of *Cortaderia* in South Africa (Henderson and Wilson, 2017), and therefore pampas plants were widely sold under the assumption that nurseries were only propagating sterile cultivars. This was problematic as there was no formal procedure put in place to test for or confirm sterility, which is why the NEM:BA regulations changed (Chetty et al., in press). Moreover, sterile cultivars can also become invasive through rhizomes and tillers, even though long distance dispersal would be limited (Henderson and Wilson, 2017).

2.4.3. Differences between *Cortaderia jubata* and *Cortaderia selloana*

Cortaderia jubata and *C. selloana* are very similar in appearance and can be difficult to distinguish morphologically by non-experts, particularly when not in flower (DiTomaso et al., 2010; Figure 2.5). There is considerable identification uncertainty between the two *Cortaderia* species and Lambrinos (2000) suggested that floral traits of *C. selloana* in California have gradually become more similar to that of *C. jubata* over the years as a result of phenotypic plasticity from environmental conditions. This

has resulted in some taxonomic confusion about *C. jubata* as the most recent revision of the genus treats *C. jubata* as a subspecies of *C. selloana* (*Cortaderia selloana* subsp. *jubata* (Lemoine) Testoni & Villamil; Testoni and Linder, 2017). Nevertheless, references in all literature and accepted taxonomic reference databases, such as Integrated Taxonomic Information System (ITIS) and Botanical Database of Southern Africa (BODATSA), still refer to *C. jubata* at the species level.

Apart from different inflorescences and breeding systems, morphological differences in the leaves can also be used to distinguish the two species (DiTomaso et al., 2010). Vegetatively, mature *C. jubata* tussocks are generally shorter and broader than the erect, fountain-like tussocks of *C. selloana* (DiTomaso et al., 2010; Figure 2.5). The leaves of *C. jubata* are typically dark green on both surfaces and comparatively flatter as they are only slightly V-shaped in the cross-section near the base. They have a hairy abaxial surface towards the base and dropping culm leaves (Lázaro-Lobo et al., 2024). In comparison, the leaves of *C. selloana* are strongly V-shaped in cross-section throughout. They are blue-green on the adaxial surface, glabrous on the abaxial surface and the culm leaves tend to arch upwards (Lázaro-Lobo et al., 2024).

The flower plumes of *C. jubata* are stiff pinkish or purplish when young fading to creamy white or dark brown as they mature (NSW WeedWise 2021; GISD 2022) and reach a greater height above the tussock than the white or silvery plumes of young *C. selloana*, fading to creamy white as it matures (DiTomaso et al., 2010; NSW WeedWise 2021; Figure 2.6). Although these traits can reliably distinguish cultivars with distinct phenotypes that breed true or are clonally propagated, morphological characters alone are often not sufficient to clearly identify all pampas grass cultivars (Ahmad et al., 2006). For example, hermaphrodite *C. selloana* plants can have plumes that can be as long as *C. jubata*, and more violet in colour than female *C. selloana*. Thus, they can look like a crossbreed between *C. jubata* and female *C. selloana* (DiTomaso et al., 2010). However, these two species of *Cortaderia* are readily distinguishable using microsatellites; therefore, genetic techniques are more accurate in identifying the species than relying on morphological traits alone (Houlistin and Goeke, 2017)



Figure 2.5: (A) *Cortaderia selloana* in the Eastern Cape, and (B) *Cortaderia jubata* in Gauteng (photo credit: Thembelihle Mbele).

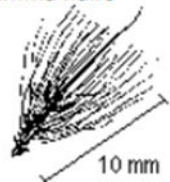
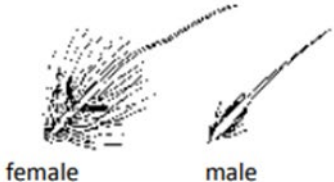
Character	Jubatagrass (<i>Cortaderia jubata</i>)	Pampasgrass (<i>Cortaderia selloana</i>)
Reproductive traits		
<ul style="list-style-type: none"> • Reproduction • Sex expression 	Seed produced asexually Female flowers only	Seed produced sexually Male and female flowers on separate plants (female plants can produce a few bisexual flowers)
<ul style="list-style-type: none"> • Chromosome number 	2n=108	2n=72
Tussock		
<ul style="list-style-type: none"> • Typical height at maturity (not including flowering stems) 	1-1.5 m (3-5 ft)	2-4 m (6-13 ft)
Leaves		
<ul style="list-style-type: none"> • Habit • Color • Tips 	Ascend more horizontally, spreading Bright green Appear broader, less coiled	More erect, fountain-like Bluish-green Appear narrower, more coiled
Flowering stems/culms		
<ul style="list-style-type: none"> • Height above tussock 	1-2 m (3-6 ft)	female: 0-1 m (0-3 ft) male: 0-2 m (0-6 ft)
Inflorescence		
<ul style="list-style-type: none"> • Immature panicle color • Mature panicle color • 2° branches • rachilla color 	Deep violet Pinkish to dingy tan Purplish or dark Purplish or dark	female: white male: white to violet white, cream, male sometimes pinkish-tan green or straw-colored green or straw-colored, male sometimes purplish or dark near spikelet base
Spikelets/Florets/Seed		
<ul style="list-style-type: none"> • Presence of anthers, stigmas (early flowering stage) • Glumes • Floret #/spikelet • Lemma hairs • Lemma length including awn • Awns • Florets showing stigmas or emerging anthers 	stigmas often with purple midvein 3-5 6-10 mm long 10-13 mm 0-4 mm longer than lemma hairs	female: stigmas male: anthers white, male sometimes purplish near base female: 5-7 male: 3-5 female: 1-10mm long male: absent female: 15-20mm male: 10-13mm female: 5-12mm longer than lemma hairs
		

Figure 2.6: Morphological features and reproductive traits of *Cortaderia jubata* and *Cortaderia selloana* (Figure taken from DiTomaso et al., 2010).

2.4.4. *Uses and economic importance*

Cortaderia species are widely cultivated around the world for ornamental purposes and have been largely available and sold in garden centres (Lambrinos, 2001; Domènech and Villa, 2008; Houliston, 2017). In many countries, *Cortaderia* species are still available commercially and frequently planted in private gardens (Tarabon et al., 2018). *Cortaderia* species are cultivated as landscape ornamentals, planted in lawns or gardens singly or in groups, as a hedge or windbreak (Drewitz and DiTomaso, 2004; Okada et al., 2007). Other than being an ornamental plant, the dense fibrous root growth from shallow short lateral rhizomes (Weed Report, 2022), make them attractive to be used to rehabilitate mines, stabilise soil, and stream banks (Drewitz and DiTomaso, 2004; Henderson, 2020). The dried leaves of pampas grass can be used to fuel fire (Bossard et al., 2000; DiTomaso, 2000; Domènech et al., 2006), and their beautiful white or pink flowers are used in the floral industry (Drewitz and DiTomaso, 2004). *Cortaderia* species also provide shelter for wildlife, such as birds and small mammals (Houliston and Goeke, 2017). A study by Pérez et al. (2021) found that *C. selloana* leaves and stems are a possible energy source and that it would be possible to transform *C. selloana* into biofuels such as bio-char, bio-oil, and gas and carbonaceous adsorbent materials. Moreover, Shadiya et al. (2022) reported a novel “green chemical route” by isolating nano silica fibers from *C. selloana* flowers that have pore-filling properties and can be used in the manufacturing of concrete.

2.5. **Impacts of *Cortaderia* invasions**

2.5.1. *Ecological impacts*

Tall-statured grasses are particularly noted for their ability to dominate plant communities, alter ecosystem function and suppress growth of neighbouring plants (Drewitz and DiTomaso, 2004). *Cortaderia* species are aggressive colonisers that can increase their density and establish in semi-natural areas in a short period of time (Domènech et al., 2006; Dellow and McMaffery, 2009). They change the vertical structure of the vegetation and compete with native plants, and once naturalised, they tend to exclude most other species and form impenetrable clumps (Domènech et al., 2006; DAISIE, 2009; Dellow and McMaffery, 2009). Prolific seed production, rapid

growth and accumulation of above- and below-ground biomass allows *Cortaderia* to acquire light, moisture and nutrients to the detriment of native plant species (Domènech et al., 2006; Dellow and McMaffery, 2009). *Cortaderia* invasions can reduce plant species diversity, life form richness, native species cover and limit secondary succession from abandoned agricultural or pastoral lands (Domènech et al., 2006).

Cortaderia invasions can alter the structure of invaded communities and exclude most other ground flora and seriously impede over-storey regeneration (Blood, 2001; Muyt, 2001). Decomposition of leaf litter of *Cortaderia* species is slow and therefore the total soil nitrogen is reduced while the carbon-nitrogen ratio is increased (Domènech et al., 2006). They increase the frequency and intensity of wildfires through the build-up of dry leaves when senescing (Domènech et al., 2006). Flowering stalks of *Cortaderia* produce large amounts of flammable material and increase fire intensity and fire hazards (Bossard et al., 2000; DiTomaso, 2000).

2.5.2. Socio-economic impacts

Cortaderia selloana leaves are sharp with cutting edges while *C. jubata* has abrasive leaves and both can cause superficial cuts to humans and animals (Domènech et al., 2006). *Cortaderia selloana* flowers and pollen cause allergies in summer (Rodríguez et al., 2021). According to AGIS (2013), in South Africa, the fluffy inflorescences of *C. jubata* cause respiratory problems to humans, especially those suffering from asthma. *Cortaderia* form dense and impenetrable stands that can reduce grazing, interfere with afforested areas, and reduce visibility, particularly in urban areas (Blood, 2001; Domènech et al., 2006; Henderson, 2020). Increased density of *Cortaderia* reduces the recreational value of invaded lands (DiTomaso et al., 2010). They can also affect structure, species composition or regeneration of sites with high conservation value (Lambrinos, 2000; DiTomaso et al., 2010).

2.6. *Cortaderia* species in South Africa

2.6.1. Occurrences of *Cortaderia* species in South Africa

Historically, only *C. selloana* was recorded to be present in South Africa, reportedly introduced in 1944 and planted extensively as an ornamental and for mine dump stabilisation (Henderson, 2020). Robinson (1984) then confirmed through morphological assessment of herbarium specimens that *C. jubata* also occurs in South Africa. *Cortaderia* species widely distributed across the country and have invaded both disturbed and native habitats (Robinson, 1984; Domènech et al., 2006). *Cortaderia selloana* has been reported in all provinces in South Africa but is most problematic in the Eastern Cape, Gauteng, KwaZulu-Natal and Western Cape and *C. jubata* has been reported in seven provinces but is problematic in Gauteng and Mpumalanga (Henderson, 2020). *Cortaderia jubata* flowers from November to February while *C. selloana* flowers from February to May (Robinson, 1984). They often occur in inaccessible areas such as high-altitude grasslands, rocky areas, coastal dunes and sandy habitats, as windbreaks together with trees, recently felled woodlands, early-stage woodland and coppice, waste deposits, swamps, and wetlands (Parsons and Cuthbertson, 2001; DAISIE, 2009). Their wide distribution is facilitated by their wide environmental and abiotic tolerances and prolific seed production (Canavan et al., 2019).

2.6.2. Management of *Cortaderia* species in South Africa

Cortaderia jubata and *C. selloana* are currently listed as category 1b species in the NEM:BA-A&IS Regulations, meaning that land occupiers are legally obliged to control them, or to remove and destroy them if possible (Henderson, 2020; Zengeya and Wilson, 2020; Sutton et al., 2021). Management options for *Cortaderia* species are available and are currently limited to mechanical and chemical control in South Africa. *Cortaderia* can be physically removed by uprooting plants and is best done after rains when the soil is moist to ensure removal of the crown and root systems (DiTomaso, 2000; NSW WeedWise, 2021). Machinery can be used to uproot dense infestations of *Cortaderia*, and plants are left to die on site to avoid any spread to areas which have not been infested (DiTomaso, 2000). Mechanical control should be done

before the flowering season and old panicles should be immediately placed into disposal bags to avoid seed dispersal (DiTomaso, 2000; NSW WeedWise, 2021). Suárez et al. (2022) explored the use of hydrothermal carbonisation as another manual control option for *Cortaderia*. Hydrothermal treatment at temperatures from 100 to 230 °C for 30 min makes both the seed inert and produces a stable carbon-enriched solid (Suárez et al., 2022).

Herbicides are generally used in areas where infestations are less dense to prevent possible chemical contamination (NSW WeedWise, 2021). Prior to foliar spray treatment, *Cortaderia* stands are burned (NSW WeedWise, 2021). However, this management option can be complicated by the occurrence of populations in inaccessible areas and on private property (Henderson, 2020). Also, their control is complicated by abundant seed production, a positive response to disturbance, and in some cases, herbicide resistance (Milton, 2004). In South Africa, Kilomax glyphosate sodium salt (700g/kg) has been mainly used for *Cortaderia* species and has been selected to avoid water pollution (Debbie Muir, pers. comm.). Ezemvelo KZN Wildlife has been using Kilomax in the Drakensberg area to treat *Cortaderia* and this has been quite successful (Ezemvelo KZN Wildlife pers. comm.; Figure 2.7).



Figure 2.7: *Cortaderia* plants (A, B and C) that have been treated with Kilomax by Ezemvelo KZN Wildlife in the Injesuthi Nature Reserve, KwaZulu-Natal (photo credit: Thembelihle Mbele).

Biocontrol has been practised in South Africa since 1910, and is the third most active country in biocontrol after the United States and Australia (Van Wilgen et al.,

2004; Schwarzländer et al., 2018). Biocontrol of grass species has rarely been attempted because of concerns of non-target damage to economically important grass crops and perceptions of poor prospects for finding host specific agents (Sutton et al., 2021). However, recent evidence is finding biocontrol of grasses promising and that it can be an effective management option (Sutton et al., 2019). A biocontrol program of invasive *Cortaderia* species has been initiated in New Zealand and two potential biocontrol agents were identified: a floral-smut fungus, *Ustilago quitensis* Lagerh. (Ustilaginales), and a planthopper, *Sacchasydne subandina* Remes Lenicov and Rossi (Hemiptera: Delphacidae). Both agents are still under investigation (Lázaro-Lobo et al., 2024).

In 2016, the gall midge, *Spanolepis selloanae* Gagné was discovered from inflorescences of *C. selloana* in Spain, Europe (Fagúndez and Lema, 2019). Its impacts on seed production were studied, from a population in northwest Spain, in order to ascertain its effectiveness in limiting sexual reproduction of *C. selloana*. It was found that the larvae of *S. selloanae* feed on the ovaries with a mean seed depletion of 74 % per plant (Fagúndez et al., 2021). Therefore, the larvae of *S. selloanae* strongly affect seed production, which is the main source of propagation of *C. selloana* and can be regarded as a potential candidate agent for the effective biocontrol of *C. selloana*. Developments in these programmes could help inform biocontrol efforts in South Africa in the future. Livestock can also be used to graze on juvenile *Cortaderia* species to prevent flowers from developing and setting seeds (NSW WeedWise, 2021). This control method proved to be successful in New Zealand (DiTomaso, 2000).

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Chapter 3: Genetic diversity and structure assessment of two invasive *Cortaderia* congeners in South Africa

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Abstract

Cortaderia species are one of the worst invasive alien grasses globally, including in South Africa, where they primarily invade riparian areas. The aim of this study was to investigate the genetic variation and structure of *Cortaderia* species in South Africa. To determine the genetic diversity, eight microsatellite primer pairs were used in 75 samples from across the plants' distribution in South Africa. Two genetic clusters were identified clearly grouping *C. jubata* separately from *C. selloana* indicating the presence of the two species, with *C. selloana* being widespread while *C. jubata* is restricted to a few areas. No genetic diversity was found in *C. jubata*, indicating that all sampled populations in South Africa are one clone while *C. selloana* has high genetic diversity. The presence of the two species and lack of geographic structuring indicates that there have likely been few introduction events. This research has contributed to the understanding of the genetic variation of *Cortaderia* in South Africa and confirmed which species are present. The results from this study can be used to guide the biological control programme of these species in South Africa.

Keywords: alien grasses, invasive alien plants, microsatellites, pampas grass

3.1. Introduction

Biological invasions are one of the most serious human-induced threats to natural ecosystems. Understanding ecological and evolutionary causes and consequences of biological invasions have important implications for management (Freeland, 2020). Understanding the phenotypic and genetic characteristics of successful invaders and invasion pathways contribute to the risk assessment, management and development of policy and legislation of alien species (Blanchet, 2012). Genetic markers such as allozymes, microsatellites and mitochondrial and nuclear DNA sequences can be used to understand many research areas of invasion biology, such as migration rates, population size, bottlenecks and kinship (Blanchet, 2012; Freeland, 2020). Microsatellites have emerged as the most popular and versatile marker type for ecological applications (Selkoe and Toonen, 2006; Hoshino et al., 2012). The rise of commercial services that can isolate microsatellites for new study species and genotype samples at reasonable prices presents ecologists with the unprecedented ability to employ genetic approaches without heavy investment in specialized equipment (Selkoe and Toonen, 2006).

Genetic analyses of invasive species have been used to identify the potential to spread and estimate the number of introduction events an alien species may have had into the adventive range (Hagenblad et al., 2015; Gaskin, 2024). It may also be used to provide information concerning contemporary gene flow, adaptive potential, relatedness among invasive populations and possible resistance to control efforts (Kelager et al., 2013). Genetic studies do not only help improve our understanding of biological invasions but also have immediate benefits by guiding management efforts on invasive species (Makhrov et al., 2014; Van de Crommenacker et al., 2015; Canavan et al., 2022). For example, a genetic study of the peppertree, *Schinus terebinthifolius* Raddi, determined that only one haplotype has been introduced into South Africa unlike in other adventive ranges where numerous haplotypes were introduced and have subsequently hybridised and become more invasive as a result. Understanding the genetics of *S. terebinthifolius* in South Africa was used to inform on management of the species and to highlight the need to prevent any further introductions of any haplotypes (Canavan et al., 2022).

The introduction history of many ornamental plants is poorly documented; hence it is not always feasible to confidently determine whether invasions have been initiated through single or multiple introductions (Prentis et al., 2009). However, methods from population genetics have the potential to help unravel the introduction history of invasive species and identify sources of introduction (Canavan et al., 2017). For example, to understand the introduction history of invasive populations of *C. selloana* in California, Okada et al. (2007) analysed microsatellite marker variation in both cultivated and invasive populations. In cultivated *C. selloana* populations, seven distinct lineages were identified and two of these accounted for the genomic origin of 78 % of the invasive *C. selloana* populations sampled (Okada et al., 2007). These results suggest that multiple cultivated genotypes are a source of invasive populations, and landscape plantings contribute to the range expansion of invasive *C. selloana* in California.

The type of reproductive strategies employed by plants can be determined through assessment of their genetic variation of populations (Gitonga et al., 2015). Sexual reproduction promotes genetic variation by producing different gene combinations. A genetic study of invasive and native populations of *C. jubata* by Okada et al. (2009) used nuclear microsatellite markers to assess clonal diversity. Their results found that introduced *C. jubata* in California, Maui and New Zealand consist of a single genetic clone, indicated by low genetic variation due to the plants reproducing through apomixis (Okada et al., 2009), which is common in invasive populations of apomictic plants in introduced ranges (Gitonga et al., 2015). However, Houliston and Goeke (2017) examined the genetic variation present in *Cortaderia* species in New Zealand using the same markers and found that *C. jubata* had more genetic variation than estimated by Okada et al. (2009). *Cortaderia jubata* in California was planted mainly for landscape purposes while in New Zealand it was planted for numerous uses (landscape, ornamental) in many different habitats, which could have resulted in multiple introductions, which may explain the higher variation than in other parts of the introduced range. Multiple introduction events generally increase the probability of variation among populations (Mimura et al., 2013; Dlugosch et al., 2016).

Genetic studies can also assist with accurate species identification such as uncovering cryptic species. Cryptic invasions occur when introduced species go

undetected because they are morphologically similar to native or alien species that are already naturalised in that area (Morais and Reichard, 2018; Canavan et al., 2020). For example, at the interspecific level, it is difficult to distinguish between the invasive *Myriophyllum spicatum* L. from the native *Myriophyllum sibiricum* Komarov (Zuellig and Thum, 2012). Problems with the identification of cryptic invasions are even more evident in taxa with unresolved taxonomy, such as *Glyceria declinata* Bréb. (Poaceae) (Gerlach et al., 2009). Chorak et al. (2019) conducted a genetic survey of invasive *Trapa* in the northeastern United States and identified a cryptic introduction of *Trapa bispinosa* Roxb. var. *iinumai* Nakano, from the People's Republic of China that was previously mistaken as *Trapa natans* L.. Therefore, the presence of cryptic invasions is likely much more widespread than commonly assumed and their correct identification often rely on molecular techniques (Roman and Darling, 2007; Garnas et al., 2016). Based on morphology, it appears that *C. jubata* and *C. selloana* have naturalised in South Africa and little is known regarding their genetic diversity, which may hinder effective management. There are also challenges in distinguishing between the two *Cortaderia* species due to similarities in their morphological traits. For example, molecular work in New Zealand found that across populations that were morphologically identified as *C. selloana*, two genetic groups were determined that may represent a cryptic *Cortaderia* species (Houliston and Goeke, 2017). To understand if this has also occurred in South Africa, information on their genetic variation is essential for understanding the amount of variability across populations. No genetic work has been done on *Cortaderia* in South Africa, and yet these species pose considerable threats to South African ecosystems.

Mechanical and chemical control options are available for pampas grasses and can be effective under certain conditions (EPPO, 2018; Sutton et al., 2021). However, these management interventions are not feasible over large spatial scales and are extremely costly (Sutton et al., 2021). A biocontrol programme for *Cortaderia* species has not yet been considered in South Africa. However, recent studies (Houliston and Goeke, 2017; Fagúndez et al., 2021) on initiating biocontrol programmes on *Cortaderia* seem promising. Significant groundwork towards developing biocontrol agents for both *C. jubata* and *C. selloana* has been made in New Zealand, making them potentially cost-effective and viable targets for South Africa (Houliston and

Goeke, 2017; Sutton et al., 2021). Biocontrol is species-specific; therefore, before initiating it, it is important to establish which species is present in the country. Two *Cortaderia* species are declared to be present in South Africa and this study sought to investigate whether the records are correct and determine if any naturalised populations have been misidentified. Therefore, the aim of this study was to determine if both species are present in the country and assess their level of genetic diversity and genetic differentiation within each population; and to conduct a population genetic structure analysis and explore their introduction history into South Africa.

3.2. Materials and methods

3.2.1. Sample collection and DNA extraction

Leaf samples of 119 *Cortaderia* plants (20 *C. jubata*, 92 *C. selloana* and seven unknowns; Appendix A) were collected from the nine provinces of South Africa during February to May of 2023 and March 2024. The nine provinces included Eastern Cape, Free State, Gauteng, KwaZulu-Natal, Limpopo, Mpumalanga, North West, Northern Cape and Western Cape (Figure 3.2.1). The minimum number of sites per province was one, and the maximum was seven, with an average of four samples collected per site. The plant species were preliminarily identified based on their inflorescence colour. Plants with white inflorescences were considered as *C. selloana* and pink inflorescences were considered as *C. jubata*. The two species have different ploidy levels with *C. selloana* having $2n = 8X = 72$, while *C. jubata* has $2n = 12X = 108$ (Okada et al., 2009). All leaf samples were collected from mature plants with a basal diameter > 1m and were at least 10 m apart from each other to achieve spatial independence of the samples. Five fresh leaves of 10 cm length were collected from young leaves of a single plant and considered as one sample. Leaf samples were kept in separate zip-locked plastic bags with silica gel to keep the samples dry until DNA extraction. Each sample of leaves was tagged with a unique identifier showing the “province-town-species-number of samples”.

For each sample, 50 mg of leaf tissue was ground to fine powder using a Qiagen® TissueLyzer to which 750 μ L of CTAB extraction buffer [2 % w/v CTAB, 100 mM Tris-HCl, 20 mM Ethylenediaminetetraacetic acid (EDTA), 1.4 M NaCl and water]

was added in a 2 ml microcentrifuge tube. The samples were incubated in a waterbath at 65 °C for 1 h after which 500 µL chloroform/isoamyl alcohol (24:1 v/v) was added, and the suspension mixed and centrifuged at 12 000 g for 10 min at 4 °C. The supernatant was transferred to a new tube, and DNA precipitated by adding 500 µL isopropanol. The tubes were incubated at room temperature for 30 min.

The samples were centrifuged at 12 000 g for 10 min at 4 °C. The supernatant was discarded, and the precipitate washed with 500 µL ice-cold 70 % (v/v) ethanol (C₂H₆O). This was followed by overnight incubation at -20 °C, succeeded by centrifugation at 12 000 g for 5 min at 4 °C. The supernatant was discarded, and the pellet air-dried for 1 hr at room temperature. The pellet was resuspended in 200 µL Tris-EDTA (TE) buffer (10 mM Tris-Cl pH 8.0 and 1 mM EDTA). The DNA was purified using a Favorgen Gel/PCR purification kit (Biotech Corp.) according to the manufacturer's specifications and eluted in 40 µL elution buffer in a microcentrifuge tube. To confirm the quality and quantity of the DNA, it was separated on a 1 % (w/v) agarose gel containing 2.5 µL of 0.5 µg/ml ethidium bromide (EtBr), in 50 ml 0.5 x Tris-acetate-EDTA (TAE) buffer [20 mM Tris-HCl pH 8.0, 0.28 % (v/v) acetic acid and 0.5 mM EDTA pH 8.0].

The DNA concentration was estimated by standard spectrophotometric methods at 260 nm and 280 nm using a Nanodrop ND-2000 Spectrophotometer (Li et al., 2013; Aboul-Maaty and Orabt, 2019). The quality of DNA samples was visualised on a 1 % (w/v) agarose gel by mixing each sample with 3 µl loading dye [0.015 % (w/v) bromophenol blue and 2.5 % (w/v) ficoll]. Simultaneously a 1 kb DNA Ladder (Thermo Scientific) was separated with the fragments on the gel for 30 min at 100 V.cm⁻¹, and the DNA was visualised with ultraviolet (UV) light illumination and photographed with a Gel Doc XR TM documentation system (Bio-Rad).

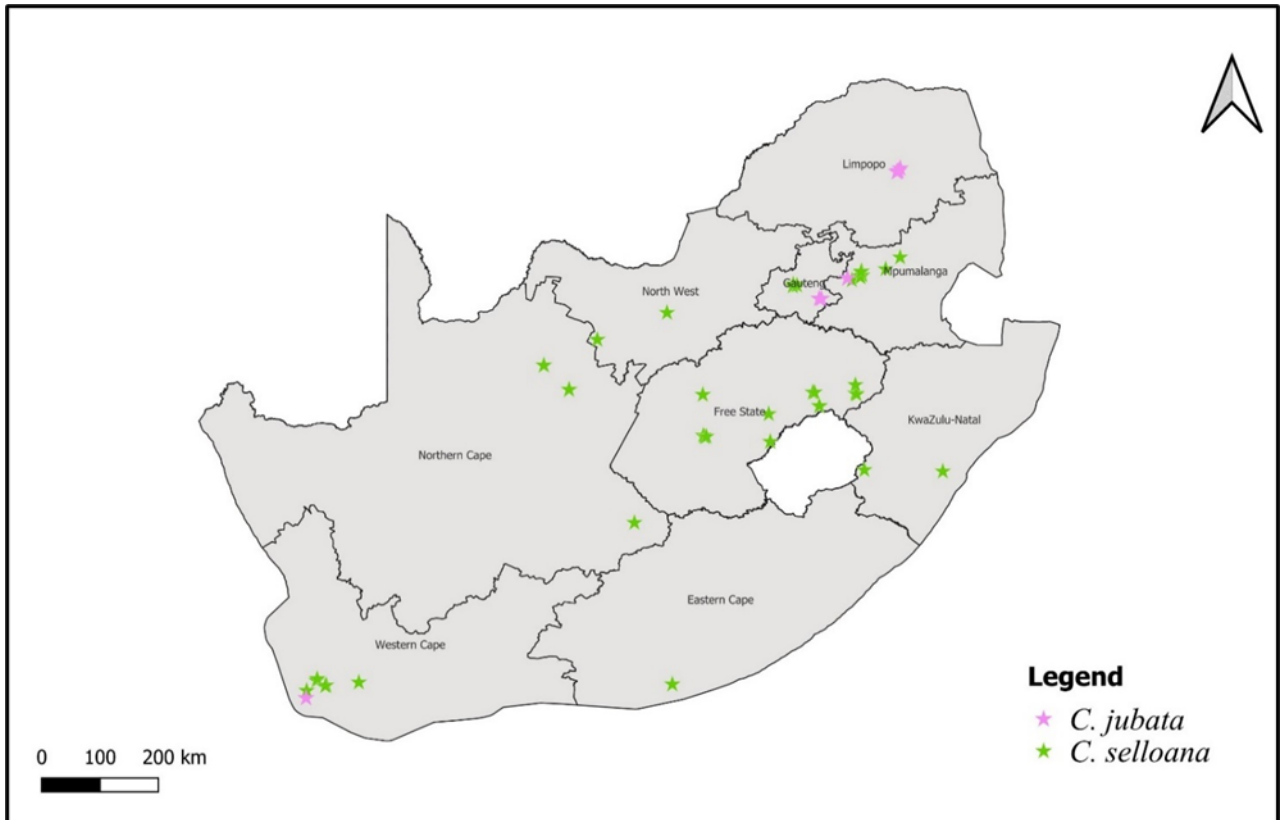


Figure 3.2.1: The distribution of the *Cortaderia* samples collected across South Africa for this study based on the identification after genetic analysis (see Appendix A).

3.2.2. Polymerase Chain Reaction and microsatellite genotyping

Out of the 119 DNA samples, 80 (65 *C. selloana*, 15 *C. jubata*) were sent to Inqaba Biotec™ for PCR set up and microsatellite genotyping. Ten microsatellite primers were developed by Ahmed et al. (2006) to study *C. selloana* populations in Europe and the United States. For this study, eight of these microsatellite primer pairs were selected according to Houliston and Goeke (2017), who used these primers to understand the genetic variation in both *C. jubata* and *C. selloana*; Cor-7, Cor-11, Cor-36, Cor-43, Cor-46, Cor-47, Cor-49 and Cor-56-1 (Table 3.2.2).

The enzyme used in the lab was a Q5 High-Fidelity 2X Master Mix (Catalogue No. M0492; NEB), used in a PCR reaction volume of 20 μ L containing at least 10 ng of gDNA, 2 μ l of multiplex primer mix (10 mM), 10 μ l Q5 High-Fidelity 2X Master Mix and nuclease free water (up to 20 μ l) (Catalogue No. E476; AMRESCO LLC, OH 44139, USA). The PCR cycling protocol was 98 °C for 30 seconds, 35 cycles of 98 °C for 30 seconds, 58 °C for 30 seconds, 72 °C for 1 minute, followed by a final extension

at 72 °C for 7 min. Two microliters of the fluorescently-labelled PCR amplicons and 15 µl LIZ500 sizing standard and Hi-Di™ Formamide (Catalogue No. 4322682 and 4311320; Thermo Fisher Scientific, Carlsbad, USA) mixture were denatured at 95 °C for 5 minutes. After denaturation, the fragments were run on a ABI 3730l Genetic Analyser (Applied Biosystems, Thermo Fisher Scientific, Carlsbad, USA), 50 cm capillary array, with POP-7™ polymer. The data was analysed and interpreted using GeneMarker V2.9.5 (SoftGenetics, State College, Pennsylvania, USA).

Table 3.2.2: Microsatellite primers for *Cortaderia* species used in this study from Ahmed et al. (2006) and the fluorescent dyes used by Inqaba Biotech™ labs.

Name	Fluorescent dye	Sequence (5'-3')	Size Range (bp)	Nucleotide Repeat
Cor-7	ATTO532	ACCTCCACAAGGATGACAGG GTCCTCCTCACCTCCATCAA	251-271	(CT) ₃₇
Cor-11	ATTO550	TTTCTTCAGTTCTGCCACGA TTTGCTGCGAATTGAAGTTG	169-210	(CT) ₄ (CA) ₈ (CT) ₃ (AT) ₄
Cor-36	ATTO565	TGCACAGTTCACAGGGAAGA ACTTGTCTGTCCCCGTAAATAAA	335-406	(CT) ₂₁
Cor-43	BLACK	GATGGAAATGCCTGGAGAGA TGGAACCCCAACAGAAGCTA	90-242	(CA) ₃₅
Cor-46	ATTO532	TGACAGTGATCCCTGACTGG CGCTAGATCCTTGAGCGTTT	205-214	(CA) ₉
Cor-47	ATTO550	AGCTTCAGGTCTGCTTCTCACT TGGTATCGTGCATCAAAGTTTC	234-241	(CA) ₇
Cor-49	ATTO565	TCCCACATGTCAGTGGAGTG GCATGTGTGATGCCGATG	115-137	(A) ₂₀
Cor-56-1	BLACK	CACCCAACCAATATCCCTGT TTTCACCCTCTGTTTTTCGTT	199-202	(CA) ₉

3.2.3. Data analysis

Fluorescent peaks were sized and scored using Geneious Prime version 2024.0 (Kearse et al., 2012). Peak size markers were aligned to ensure amplified peaks could be aligned by fragment size. Scoring was completed using a binary matrix (1 = presence, 0 = absence of alleles) to interpret markers as dominant (Houliston and Goeke, 2017). The scoring was modified from conventional microsatellite analysis (co-dominant markers) due to, 1) accounting for high ploidy levels within *Cortaderia* species, 2) the inability to assign dosage to the different markers and 3) some leaf material was collected from plants not flowering and therefore could not be assigned morphologically to one species or the other (Houliston and Goeke, 2017). Summary statistics of genetic diversity indices was prepared in GenAlEx version 6.5 (Peakall and Smouse, 2012). The observed number of multilocus genotypes for each species, expected number of multilocus genotypes at the smallest sample size ≥ 10 based on rarefaction, Shannon-Wiener Index of multilocus genotypes diversity, Stoddart and

Taylor's Index of multilocus genotypes diversity, Simpson's Index, Evenness, Nei's unbiased gene diversity, index of association and the standardized index of association were calculated per species. The South African *Cortaderia* genetic data results were then compared with those from New Zealand, however, they were not analysed together.

Pairwise genetic distances were calculated based on the number of shared alleles per locus (Euclidean distances). The output matrix of genetic distances was then used to prepare a Principal Coordinate Analysis (PCoA) plot in GenAlEx. STRUCTURE version 2.3.4 (Pritchard et al., 2000), to examine the optimal number of distinct populations or assignment classes across and within the *Cortaderia* species, using the admixture model that assumed independent allele frequencies. The burn-in period was set at 200 000, followed by 350 000 MCMC steps, with 10 runs performed for each value of K. K-values ranged from 1–10, and no prior population data were included in the model. Structure Selector (Li and Liu, 2018) was used to determine the optimal number of K using the Evanno method (Evanno et al., 2005). The cluster membership and assignment of samples into each cluster for *C. jubata* and *C. selloana* was visualised using the *compoplot()* and *assignplot()* functions in the R package adegenet (Jombart, 2008).

3.3. Results

There was considerable variation in DNA quality using A260/A280 ratio and quantity among the samples, with the quantity of DNA ranging from negative (-) 180.8 to 1048.2 ng/ μ l. Due to financial restrictions, from the 119 samples that were collected, only 80 were sequenced. The sequenced samples were selected to include all localities sampled and then to have a few sites with more than one sample. Five of the 80 samples had no allele amplification and were removed from the analysis. Therefore, in total, 75 individuals (nine *C. jubata* and 66 *C. selloana*) from South Africa were successfully genotyped. Summary statistics for *C. jubata* and *C. selloana* revealed that nine *C. jubata* plants sampled across South Africa shared a single multilocus genotype (Table 3.3.1). There was no genetic diversity found across all populations of *C. jubata* in South Africa. The 66 individuals of *C. selloana* were found to have a higher genetic diversity compared to the 486 individuals of *C. selloana* from New Zealand (Table 3.3.1).

Table 3.3.1 Summary statistics for *Cortaderia selloana* and *C. jubata* from South Africa compared with New Zealand (Houliston and Goeke, 2021). In New Zealand two entities thought to be cryptic species of *C. selloana* were found and are referred to here as type 1 and type 2: *n*, number of samples; *Na*, number of alleles; *Ne*, number of effective alleles; *I*, Shannon's information index; *He*, estimated expected heterozygosity; *uHe*, unbiased estimated expected heterozygosity. Values in parentheses are Standard Errors of the Means.

Range	<i>n</i>	<i>Na</i>	<i>Ne</i>	<i>I</i>	<i>He</i>	<i>uHe</i>
South Africa						
<i>C. selloana</i>	66	1.680 (0.111)	1.322 (0.071)	0.301 (0.054)	0.195 (0.038)	0.196 (0.038)
<i>C. jubata</i>	9	0.600 (0.100)	1 (0.000)	0	0	0
New Zealand						
<i>C. selloana</i> type 1	460	1.804 (0.062)	1.151 (0.029)	0.148 (0.024)	0.093 (0.017)	0.093 (0.017)
<i>C. selloana</i> type 2	26	0.913 (0.103)	1.145 (0.027)	0.154 (0.023)	0.094 (0.015)	0.096 (0.016)
<i>C. jubata</i>	96	0.750 (0.099)	1.099 (0.026)	0.098 (0.020)	0.061 (0.014)	0.061 (0.014)

The two *Cortaderia* species present in South Africa were clearly separated into two clusters based on their unique alleles using a PCoA (Figure 3.3.1). The optimal value of *K* from the STRUCTURE analysis for the data was *K* = 2, as determined by Structure Selector, which clearly separated *C. selloana* and *C. jubata* (Figure 3.3.2). From the STRUCTURE results, the Evanno method determined two distinct clusters that separate *C. jubata* and *C. selloana* based on their unique alleles. The number of alleles scored per individual for each of the species for each locus, the total number of alleles per locus, and allele size range for each species, differentiated the two species. Some samples (*n* = 11; 55%) that were erroneously identified as *C. jubata* using inflorescence colour grouped together with *C. selloana* samples, meaning that

they are *C. selloana* based on their genetic profile (refer to Appendix A with sample information). In addition, alleles for both *C. jubata* (pink) and *C. selloana* (green) are unique and there were few shared alleles (Figure 3.3.3), showing no evidence of hybridisation.

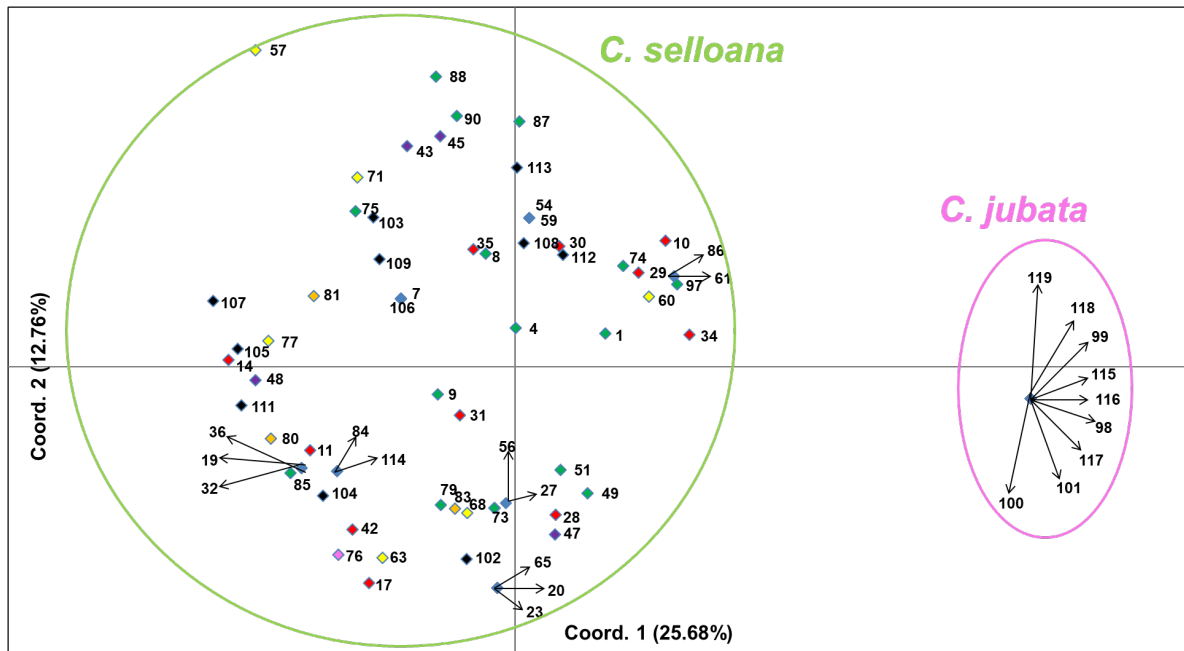


Figure 3.3.1: Principal Coordinates analysis (PCoA) built on Euclidean genetic distances between *Cortaderia jubata* and *Cortaderia selloana* samples in South Africa using Cor-7, Cor-11, Cor-36, Cor-43, Cor-46, Cor-47, Cor-49 and Cor-56-1 microsatellite primers. Samples with missing data were excluded. Oval colours represent different species in South Africa; pink —*C. jubata* and green — *C. selloana*. Colours on samples represent geographic area defined by sampling region in South Africa; green — Free State, red — Northern Cape, purple — Gauteng, pink — KwaZulu-Natal, yellow — Western Cape, black — Mpumalanga, orange — Eastern Cape, blue — represented samples collected from different provinces but clustered together, displaying genetic similarity.

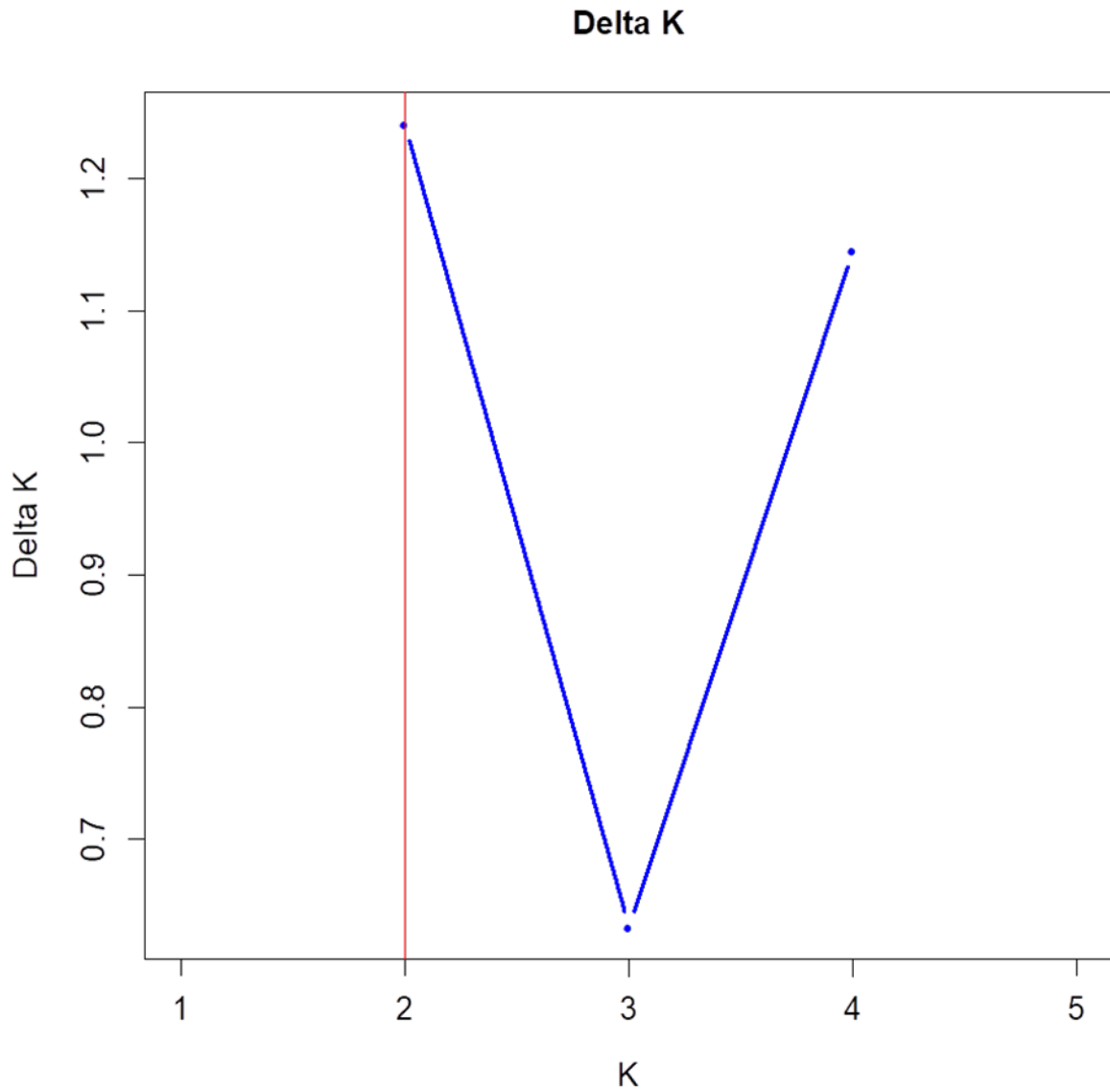


Figure 3.3.2: Results from Structure Selector (Li and Liu, 2018) showing the estimated number of populations as $K = 2$ based on 75 populations of *Cortaderia jubata* and *C. selloana* in South Africa, using eight microsatellite primers and the Evanno method according to Earl and Holdt (2012).

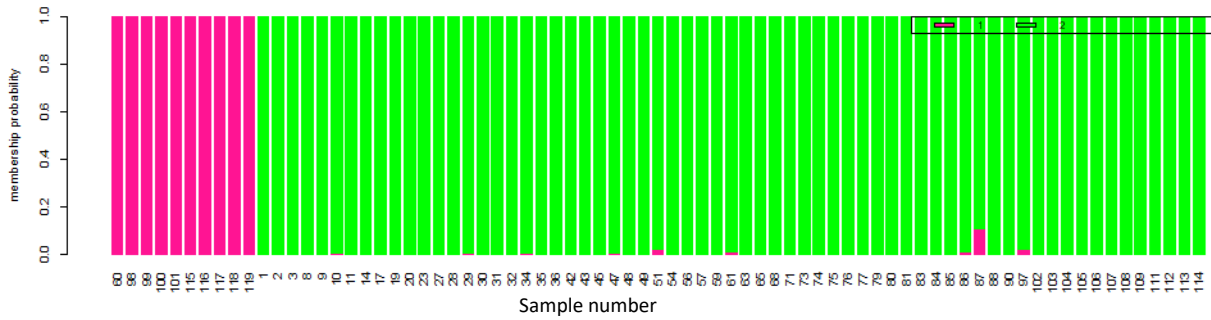


Figure 3.3.3: Compoplot visualising the probability of an individual from *Cortaderia jubata* and *C. selloana* samples grouping to a determined ‘genetic lineage’ (two assigned lineages, $K = 2$, determined by the Evanno method (see Fig. 3.3.2) using the adegenet R package (Jombart, 2008). 1. Samples in pink show all individuals belonging to the *C. jubata* cluster and 2. Samples in green shows all individuals belonging to the *C. selloana* cluster.

All *C. selloana* plants sampled across South Africa are closely related. Some samples from different provinces clustered together (Figure 3.3.1). For example, sample 11 and 12 from Khathu, Northern Cape clustered with sample 36 from Tokai, Western Cape and sample 34 from Stellenbosch, Western Cape clustered with sample 50 from Bloemfontein, Free State. According to STRUCTURE analysis, cultivated and naturalised populations of *C. selloana* were not genetically distinct from each other. The F-value for *C. selloana* was -1 as they were clonal (Table 3.3.2). The PCoA of *C. selloana* showed no sub-structuring of the species (see supplementary data, Figure 3.3.1 and 3.3.2).

Table 3.3.2 F-Statistics over all populations of *C. selloana* in South Africa

Locus	F
1	-0,010
2	0,132
3	-0,248
4	0,497
5	1,000
6	-0,225
7	-0,206
8	-0,204
9	0,161
10	0,496
11	0,311
12	-0,200
13	-0,181
14	-0,200
15	-0,183
16	0,072
17	-0,224
18	0,066
19	0,097
20	-0,196
21	0,216
22	-0,196
23	-0,229
24	0,181
25	0,050

3.4. Discussion

Cortaderia species are aggressive invaders globally, including in South Africa. The genus is currently widespread in South Africa due to its ability to invade both disturbed and pristine habitats. The aim of this study was to accurately identify *Cortaderia* species present in South Africa, assess if there were cryptic species and to understand their introductory history. Genetic analyses confirmed that there are two *Cortaderia* species, *C. jubata* and *C. selloana*, present in South Africa, which are distinguishable genetically. According to Connor (1983), there are only two species of sexually reproducing *Cortaderia* (*C. araucana* and *C. selloana*) and therefore they are the only two species that can hybridise with each other. As expected, due to differences in their breeding systems, there was no evidence of hybridisation between *C. jubata* and *C. selloana* as alleles were unique to each *Cortaderia* species.

In South Africa all *C. jubata* samples were found to be a single multi-locus genotype, indicating that all *C. jubata* populations in South Africa are essentially one clone. These findings are similar to those of previous studies in other areas that have found introduced *C. jubata* to be clonal from horticultural introductions (Okada et al., 2009). Clonal plants generally have had single introduction events, and have resource translocation among the ramets (clonally formed offspring) (Harper, 1977; Liu et al., 2016). Clonal integration has some characteristics that can make clonal plants more vigorous and invasive in new habitats. These characteristics include plasticity in response to local and non-local conditions, labour division with organ specialisation for acquiring locally abundant resources, foraging behaviour by selective placement of ramets in resource-rich microhabitats, and avoidance of intraclonal competition (Liu et al., 2016). Clonal integration also allows clonal plants to effectively cope with environmental heterogeneity, by alleviating local resource shortages, buffering environmental stresses and disturbances, influencing competitive ability, increasing invasiveness, and altering species composition and invasibility at the community level (Dong et al., 2015; Liu et al., 2016). These characteristics can increase the performance of clonal plants over sexually reproducing plants (Roiloa et al., 2010; Wang et al., 2017). Song et al. (2013) examined the relationship between the effect of clonal integration and measures of the degree of invasiveness around the world in 60

clonal plant species and found that clonal integration contributes to their invasive success.

Cortaderia selloana is more widespread than *C. jubata* in South Africa, being present in many home gardens and private properties as an ornamental or garden plant (personal observations). From the 66 samples of *C. selloana* included in this study, we found 57 multi-locus genotypes and a higher diversity than in other parts of the introduced range such as California and New Zealand. Previous studies (e.g. Okada et al., 2007; Houliston and Goeke, 2017) have shown that certain genotypes of *C. selloana* have a greater invasive capacity. In South Africa, two populations were found across all samples (Figure 3.3.2). This indicates that there likely haven't been multiple introductions of different genetic lineages; as they are genetically similar across South Africa (Canavan et al., 2017). Nurseries in South Africa were previously given concessions to sell sterile cultivars (Chetty et al., in press); hence we would have expected populations from home gardens or private properties to group differently from naturalised populations, assuming many of these plants were cultivars bought from nurseries. However, *C. selloana* populations from home gardens were very similar to those from the naturalised populations, indicating that populations are likely to have come from a common source that was not sterile. These findings are similar to the Okada (2007) study in California which suggested that cultivated plantings are sources of invasive populations.

Biocontrol programmes for *Cortaderia* have not yet been initiated in South Africa; however, significant groundwork towards identifying biocontrol agents for both *C. jubata* and *C. selloana* has been made in New Zealand. Two potential biocontrol agents were identified, *Ustilago quitensis* Lagerh. and *Sacchasydne subandina* Remes Lenicov and Rossi (Hayes 2014). These programmes are still in progress and are currently in the host specificity testing stages. Another potential biocontrol agent for *C. selloana*, *Spanolepis selloanae* Gagné, was discovered and first reported in Spain. This biocontrol agent is very promising as its larvae were found feeding on the ovaries of *C. selloana* with a mean seed depletion of 74 %, which would result in reduced spread (Fagúndez et al., 2021). This programme is also currently at the host specificity testing stages. Prospects are also promising for *C. jubata* as it was found to be one clone. Previous studies have determined that the rate of success of a

biocontrol programme is often higher for asexually reproducing plants compared to species with high genetic diversity (Burdon and Marshall, 1981; Paynter et al., 2012). Depending on the outcome of these programmes elsewhere, South Africa may be able to implement transfer programmes of these agents to release in the country.

The presence of only one clone for *C. jubata*, higher genetic diversity for *C. selloana* than in other introduced ranges, and no presence of hybrids, has important implications for management in South Africa. The absence of hybrids improves the possibility of successful biocontrol programmes (Reid et al., 2023). Hybridisation of IAPs complicates efforts to develop biocontrol because they can differ from the plants in the native range where natural enemies have evolved (Paterson et al., 2009; Reid et al., 2023). Therefore, the legislation must ensure that no further introductions are allowed into the country that might result in new genotypes or cryptic species being introduced.

3.5. Conclusion

This study determined that there has likely not been multiple introductions of *C. selloana* into South Africa, as *C. selloana* populations across the country are closely related, with no geographic structuring and differentiation between cultivated and naturalised populations. National regulations of the plant should ensure that no new genotypes of *Cortaderia* species are introduced through the horticultural trade. This study also provided evidence that morphological assessments of inflorescence colour alone are not enough to distinguish the two *Cortaderia* species. This potential for misidentification amongst non-experts may have resulted in some records of their distribution being incorrect in South Africa. *Cortaderia jubata* was found to be restricted to northern areas of the country and it is not as widely distributed as *C. selloana*. Determining the genetic diversity and confirming which *Cortaderia* species are present in South Africa has important implications for management and the future of a biocontrol program.

3.6. References

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Chapter 4: Seed germination of cultivated, naturalised and floristically traded *Cortaderia* species in South Africa

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TJM, KC & SLS: Planned and discussed the study design

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Abstract

Cortaderia species, *C. jubata* and *C. selloana* have become invasive in South Africa. Although the National Environmental Management: Biodiversity Act (NEM:BA) (Act 10 of 2004): Alien and Invasive Species regulations (A&IS regs) forbids the trade of pampas grass, the growing popularity of pampas grass inflorescences for home décor and events is a concern. This study aimed to test the seed viability of cultivated, naturalised and traded inflorescences of *Cortaderia* in South Africa to determine whether the trade in inflorescences poses a threat, by potentially facilitating new introductions, and so adding to the invasions of these species. Seeds were collected from inflorescences of naturalised populations from across nine provinces, and traded seeds were bought from retail and informal trade. To assess seed viability and germination success of seeds from the different sources, three methods were used: (1) a triphenyl tetrazolium stain, (2) germination trials in a growth chamber, and (3) germination trials in potting soil in a greenhouse. Lemongrass, *Cymbopogon citratus*, was used as a control. The data was analysed using IBM SPSS version 29.0. The results from the triphenyl tetrazolium stain showed no significant difference between *C. selloana* and *C. jubata*'s seed viability ($P = 0.277$). *Cortaderia jubata* and *C. selloana* had an average of 54.28 and 71.66 % seed viability, respectively. For germination trials in a growth chamber, non-significantly higher germination success was found for *C. selloana* (68.89 %) compared to *C. jubata* (52.62 %) ($P = 1.00$). Under greenhouse conditions, germination success for *C. jubata* and *C. selloana* was statistically similar ($P = 0.362$) with an average germination success of 62.54 and 79.15 %, respectively. Seed viability of cultivated and naturalised *Cortaderia* inflorescences differed significantly to formally traded inflorescences ($P = 0.022$ and $P = 0.018$, respectively) but not significantly to informally traded inflorescences ($P = 0.142$ and $P = 0.182$, respectively). Naturalised populations of both *Cortaderia* species had a significantly higher germination success (65.69 %, 74.35 %) than the formally (25.00 %, 5.33 %) and informally traded populations (28.75 %, 35.56 %) under growth chamber and greenhouse experiments, respectively. Viability and germination success of seeds from cultivated *Cortaderia* inflorescences were statistically similar to those from naturalised inflorescences ($P = 0.788$, $P = 1.00$, $P = 1.00$) while formally traded inflorescences were statistically similar to informally traded inflorescences ($P =$

0.626, $P = 1.00$, $P = 1.00$) across triphenyl tetrazolium stain, growth chamber and greenhouse experiments, respectively. The window period for mature seeds is very narrow and seeds were not found on all flowers collected outside of this period. These results suggest that traded seeds of *Cortaderia* are often not sterile and could thus promote invasion and further spread of *Cortaderia* species. Effective management of *Cortaderia* species must focus on enforcing legislation to stop this pathway of spread, and reduce new seed recruitment, particularly during their short flowering season.

Keywords: alien grasses, invasive alien plant, ornamental trade, pampas grass

4.1. Introduction

The success of alien plant species depends largely on the biological attributes of the species and appropriate environmental conditions (Lonsdale, 1999; Gioria et al., 2018). Seed germination, large seed production and the ability to germinate and grow in a broad range of environmental conditions are key traits for successful establishment, growth and further expansion of many successful invaders (Van Kleunen et al., 2016). Production of large quantities of seeds by alien plants results in a greater number of individual colonisation opportunities (Lake and Leishman, 2004). Understanding the dispersal mechanisms of these seeds is crucial to effective management (Leung et al., 2002). Wind dispersed species, such as *Cortaderia*, commonly have light structures on their seeds that can act as wings, plumes or balloons, allowing seeds to travel long distances and land in a wide range of new habitats (Thomson et al., 2011; Planchuelo et al., 2016). Soomers et al. (2013) reported that plants whose primary dispersal method is wind may also be effectively dispersed by water. All these traits confer weediness and success for IAPs.

The global ornamental horticultural trade has expanded significantly since the 1950s (Huang et al., 2023) and is characterised by the deliberate introduction of alien species to many areas outside their native range (Mack, 2003). Mack and Enberg (2002) found that 65 % of invasive plants introduced into Australia between 1971 and 1995 were ornamentals. In addition, Dehnen-Schmutz et al. (2007) showed that plant nurseries generally sell more alien than native species and that prices for alien species are significantly lower than those of native species. This has resulted in the plant trade being a key pathway for the introduction of IAPs (Faulkner et al., 2020). In Africa, the ornamental plant trade has also been shown to be a leading cause of alien plants escaping cultivation (Faulkner et al., 2016, 2020), and as a result the number of IAPs naturalising in native ecosystems is steadily increasing (Faulkner et al., 2020; Van Wilgen et al., 2020; IPBES, 2023). The ornamental horticultural industry recognises the need for action against the negative impacts of IAPs and has developed techniques to induce sterility for certain popular ornamentals with a high risk of spreading (Freyre et al., 2016). For example, the triploid *Hibiscus syriacus* L. cultivar “Diana” sets very little fruit, which contrasts with the diploid species that sets a large amount of fruit (Niemiera and Holle, 2009). Efforts to breed sterile plant cultivars are

still rare; therefore, there is still a limited number of ornamental alien species for which sterile cultivars have been developed (Bechtloff et al., 2019).

Although seed sterility is often considered a solution to reducing the risks of the ornamental trade spreading alien species, there are still challenges regarding proving the sterility of the seeds. For example, vetiver grass, *Vetiveria zizanioides* (L.) Nash has been extensively used because of its ability to stop soil erosion, increase soil fertility, increase forage production, purify water, and decrease water pollution (Li et al., 2004; Kim et al., 2022). However, it has also been found to be invasive in Australia, South Africa, Thailand, Hawaii, and the southern United States (Li et al., 2004; Truong et al., 2008). To reduce its invasiveness, a sterile cultivar that flowers but sets no seeds, registered as 'Monto vetiver', was developed (Li et al., 2004). However, several "sterile" cultivars that have been marketed for years have since been proven fertile (Li et al., 2006). Anderson and Ascher (1993) determined fertility levels of several "sterile" cultivars of purple loosestrife and showed that these plants are not sterile.

Poaceae is arguably the most successful graminoid family in terms of its global occurrence in almost all ecosystems with angiosperms, its ecological dominance in many ecosystems, and high species richness (Macphail and Hill, 2002; Blair et al., 2014). Linder et al (2018) suggested that the success of grasses is best understood in the context of their capacity to colonise, persist, and transform environments. Attempts to develop sterile cultivars of invasive ornamental grasses have been made. According to Dorner (2002) and Granite (2007), a combination of an annual growth form and sterility results in plants that survive only one growing season. However, Beyers (2008) documented the sterile annual hybrid grass variety Regreen (*Triticum aestivum* × *Elytrigia elongata*) persisting into a second growing season after failing to die at the end of the first season. Both *T. aestivum* × *E. elongata* and Quickguard (*Triticum* sp. × *Secale* sp.) are described as "sterile", yet it was noted that they both produce viable seed when exposed to pollen from wheat (*T. aestivum*) or other *Tritosecale* spp., respectively (Granite, 2007). Mooris and Schupp (2009) also investigated whether the sterile annual hybrid cereal grasses were sterile. They found that both types of grass produced viable seeds under greenhouse conditions, indicating a lack of true sterility, which may contradict management goals. There are also developed sterile cultivars of pampas grass known as Pumila (*Cortaderia selloana*

Schult. 'Pumila') (Robacker, 1993; Ahmad et al., 2006). However, this cultivar is now known to produce many viable seeds (Ahmad et al., 2006). In South Africa, two cultivars of *Cortaderia*, Silver Stripe and Gold Band, were listed on the National Regulations as sterile (Chetty et al., in press) and were exempted for trade. However, due to concerns about their potential weediness, their trade has been banned.

Cortaderia jubata and *C. selloana* have been widely cultivated around the world as ornamental garden plants and distributed around the world through the global nursery trade, and their plumes are commonly sold as decorative dried flower arrangements (Oakes, 2012; Roldão et al., 2023). They were introduced and cultivated in South Africa for several purposes, including for ornamental trade, erosion control, creating windbreaks and mine dump stabilisation (Henderson, 2020; Sutton et al., 2021). However, they have long since escaped cultivation and now invade grasslands, roadsides, wastelands, rivers and seasonally wet habitats (Henderson, 2020; Sutton et al., 2021). *Cortaderia* abundantly produces small wind-dispersed seeds which are also well-suited to dispersal by water (Parsons and Cuthbertson, 2001; DAISIE, 2009). For *C. jubata* and *C. selloana*, germination generally occurs in spring and seedlings will establish if there is adequate moisture and light (DiTomaso et al., 2010; Lázaro-Lobo et al., 2024). Once naturalised, *Cortaderia* develops strong tussocks with vigorous basal growth.

Little information is known about the seed biology and germination characteristics of *Cortaderia* species in South Africa. Understanding the characteristics of *Cortaderia* species' reproductive biology is important because seeds are the primary pathway for spread (DiTomaso et al., 1999). In addition, knowledge of seed germination of IAPs is crucial for predicting future spread and developing sustainable control and restoration measures (Gioria et al., 2018). Few control strategies are available for *Cortaderia* in South Africa and no biological control (hereafter biocontrol) programmes have yet been initiated. The available control strategies include mechanical removal and herbicide applications.

In the past, exemptions were made to allow both species to be traded, under the condition that the cultivars sold in nurseries were sterile. However, this trade was recognised as problematic as there was a rapid increase of *Cortaderia* species populations between 2000 and 2016 and no formal process for proving sterility

(Henderson and Wilson, 2017). When the national regulations were updated in 2020, the trade of both species was banned in South Africa (South African Department of Forestry, Fisheries and the Environment, 2021). Although the national regulations forbid the trade of *Cortaderia*, the continuing popularity of *Cortaderia* inflorescences for home decorations and special events is of concern, and the inflorescences are still being sold through retail and vendors (Sutton et al., 2021). Most suppliers often acknowledge the environmental risk of selling *Cortaderia* inflorescences by communicating to customers that they sterilise the seeds; providing statements such as, 'our pampas has been heat-bleached, which kills the seeds (preventing it from propagating or spreading)' (Bloom Space, 2024). However, other suppliers are often unaware of these national regulations and do not take any steps to reduce the spread of seeds. For example, informal traders on the streets are unlikely to have treated the inflorescences, meaning this informal pathway might be the most important pathway for the spread of these species in South Africa. The aim of this study was to explore seed viability in cultivated, naturalised and traded populations of *Cortaderia* species in South Africa to understand whether their trade in South Africa is fueling new invasions by spreading viable seeds, and if the historical trade of supposedly 'sterile' *Cortaderia* cultivars has resulted in some naturalised populations having sterile seeds.

4.2. Material and methods

4.2.1. Site and sample collection

Inflorescences of two *Cortaderia* species were collected from naturalised populations across the nine provinces of South Africa (Eastern Cape, Free State, Gauteng, KwaZulu-Natal, Limpopo, Mpumalanga, North West, Northern Cape and Western Cape) from February 2023 to May 2024. (Figure 4.2.1). Selected individuals were at least 10 m apart to reduce sampling genetically similar individuals (Hill et al., 2005). Inflorescences were collected from mature plants (basal diameter > 1 m) with more than two inflorescences. The inflorescences were kept in separate paper bags until seed removal. Each inflorescence bag was categorised into species according to their inflorescence colour. A total of 73 inflorescences, for both species, were collected from naturalised populations and 11 from cultivated populations.

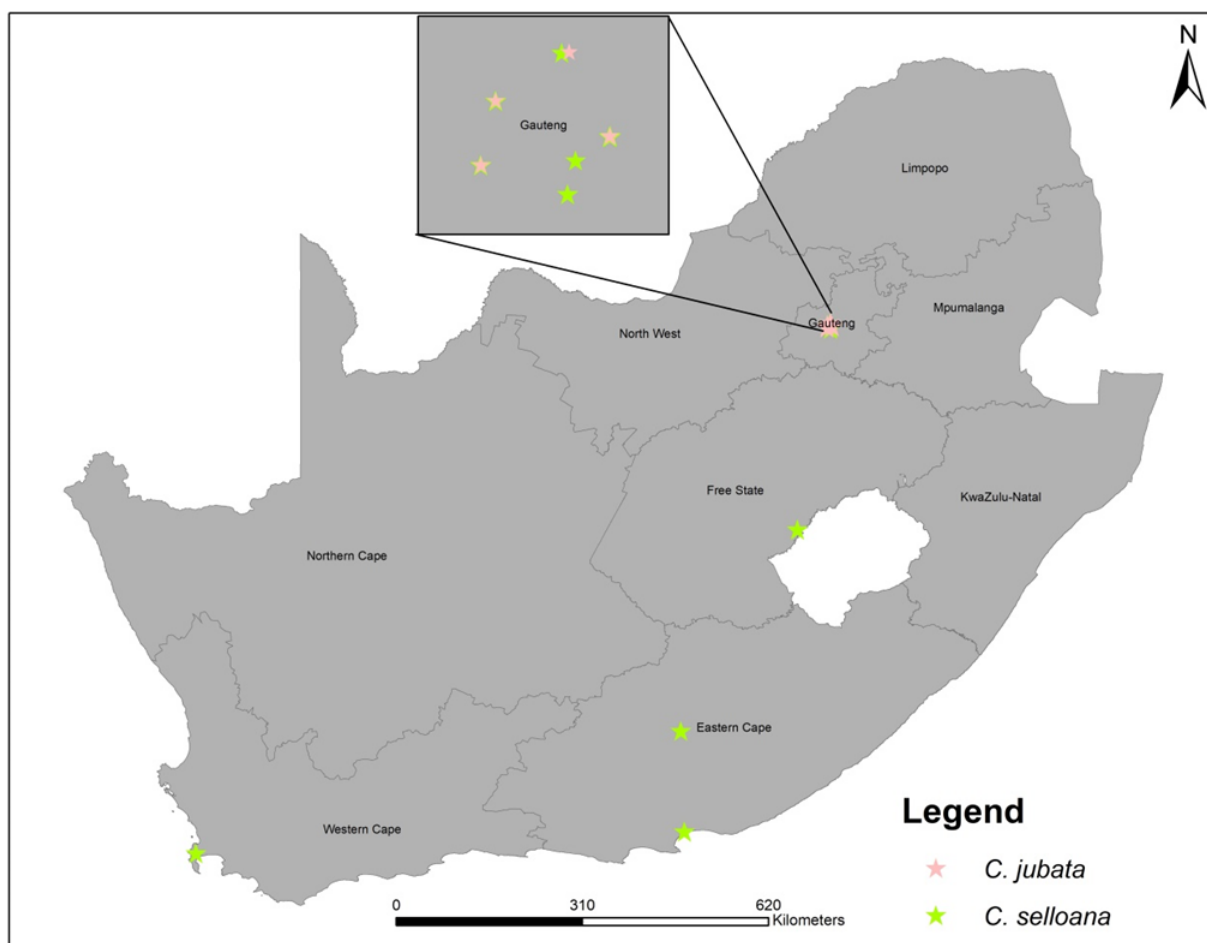


Figure 4.2.1: The distribution of the *Cortaderia* samples across South Africa included in this study, including inflorescences that had mature seeds.

Naturalised populations refer to inflorescences that were collected from populations that are self-sustaining in habitats that have no signs of having been intentionally planted. Cultivated populations refer to inflorescences that were intentionally planted in private properties such as home gardens. Formally traded refers to inflorescences that were sold in commercial stores, including florists and online shops, which often claimed to have bleached flowers, but this was not always stated. Informally traded refers to traders selling on the street and did not claim to treat the flowers and generally collected from naturalised populations themselves (T. Mbele pers. observ.). For formally and informally traded *Cortaderia* inflorescences, a population is represented by a supplier (Table 4.2.1). A minimum number of one bunch of inflorescences was bought per supplier and a maximum of two was bought if the supplier had both *C.*

jubata and *C. selloana*. The minimum number of stems per bunch was ten and the maximum was 15. In total, there were seven *C. jubata* and 21 *C. selloana* inflorescences from naturalised populations. There were four cultivated inflorescences that had seeds and all were *C. selloana*; 24 naturalised and 13 traded populations of the combined species (Table 4.2.1). From the 13 traded populations, five were from the formal trade and eight were from the informal trade. For both naturalised and traded populations, all inflorescences had no seeds outside of the flowering season.

Inflorescences of *Cortaderia* were bought from different formal (florists, online, social media platforms) and informal traders (street vendors) in and out of the flowering season across South Africa (Table 4.2.1). Formally traders were identified by carrying out an exhaustive search of online trade was done including the search words 'pampas' and/or 'cortaderia'. All search results relevant to South Africa were checked and all known retailers were purchased from. In addition, inflorescences were purchased from florist shops when they were available. No nurseries were found to be selling pampas grass.

Informal traders were identified on the streets or roadsides where they were observed selling pampas grass. In total, nine inflorescences were bought from informal trade and ten from formal trade. However, from the nine inflorescences from the informal trade, one inflorescence did not have seeds and from the ten inflorescences bought from formal trade, five did not have seeds. Inflorescences were bought from Gauteng and KwaZulu-Natal provinces because that is where the suppliers we found were based. However, all inflorescences that had seeds and used in the experiments were from Gauteng because those bought from KwaZulu-Natal had no seeds.

Table 4.2.1: The *Cortaderia* inflorescences included in this study collected from naturalised populations or bought from commercial (formal) and informal traders. Only inflorescences that had mature seeds are included here.

	Source	Species	GPS coordinates/ trade	Town/ supplier
Cultivated	Cultivated	1. <i>C. selloana</i>	-32.2197; 25.7114	Cradock, Eastern Cape
	Cultivated	2. <i>C. selloana</i>	-26.1537; 27.9823	Johannesburg, Gauteng
	Cultivated	3. <i>C. selloana</i>	-26.1889; 27.9562	Johannesburg, Gauteng
	Cultivated	4. <i>C. selloana</i>	-34.05481; 18.43293	Tokai, Western Cape
Naturalised	Naturalised	5. <i>C. selloana</i>	-33.7285; 25.7654	Port Elizabeth, Eastern Cape
	Naturalised	6. <i>C. selloana</i>	-33.7285; 25.7654	Port Elizabeth, Eastern Cape
	Naturalised	7. <i>C. selloana</i>	-33.7285; 25.7654	Port Elizabeth, Eastern Cape
	Naturalised	8. <i>C. selloana</i>	-33.7285; 25.7654	Port Elizabeth, Eastern Cape
	Naturalised	9. <i>C. jubata</i>	-26.153; 27.9823	Johannesburg, Gauteng
	Naturalised	10. <i>C. jubata</i>	-26.1533; 27.9821	Johannesburg, Gauteng
	Naturalised	11. <i>C. selloana</i>	-26.153; 27.9825	Johannesburg, Gauteng
	Naturalised	12. <i>C. selloana</i>	-26.154; 27.9825	Johannesburg, Gauteng
	Naturalised	13. <i>C. selloana</i>	-26.1681; 27.9612	Johannesburg, Gauteng
	Naturalised	14. <i>C. jubata</i>	-26.1533; 27.9821	Johannesburg, Gauteng
	Naturalised	15. <i>C. jubata</i>	-26.1711; 27.9023	Johannesburg, Gauteng
	Naturalised	16. <i>C. jubata</i>	-26.1712; 27.9025	Johannesburg, Gauteng
	Naturalised	17. <i>C. selloana</i>	-26.1709; 27.9023	Johannesburg, Gauteng
	Naturalised	18. <i>C. selloana</i>	-26.1017; 27.9526	Johannesburg, Gauteng
	Naturalised	19. <i>C. jubata</i>	-26.1312; 27.9116	Johannesburg, Gauteng
	Naturalised	20. <i>C. jubata</i>	-26.1011; 27.9571	Johannesburg, Gauteng
	Naturalised	21. <i>C. selloana</i>	-26.1315; 27.9118	Johannesburg, Gauteng
	Naturalised	22. <i>C. selloana</i>	-26.189; 27.9562	Johannesburg, Gauteng
	Naturalised	23. <i>C. selloana</i>	-29.2006; 27.4635	Ladybrand, Free State
	Naturalised	24. <i>C. selloana</i>	-29.2008; 27.4635	Ladybrand, Free State
	Naturalised	25. <i>C. selloana</i>	-29.201; 27.4634	Ladybrand, Free State
	Naturalised	26. <i>C. selloana</i>	-29.2012; 27.4632	Ladybrand, Free State
	Naturalised	27. <i>C. selloana</i>	-29.2013; 27.4632	Ladybrand, Free State
	Naturalised	28. <i>C. selloana</i>	-29.2015; 27.4631	Ladybrand, Free State

Traded	Informal	29. <i>C. selloana</i>	Fordsburg, Gauteng	Anonymous 1
	Informal	30. <i>C. jubata</i>	Fordsburg, Gauteng	Anonymous 1
	Informal	31. <i>C. selloana</i>	Johannesburg, Gauteng	Vendor 1
	Informal	32. <i>C. selloana</i>	Johannesburg, Gauteng	Vendor 2
	Informal	33. <i>C. selloana</i>	Johannesburg, Gauteng	Vendor 3
	Informal	34. <i>C. selloana</i>	Johannesburg, Gauteng	Vendor 4
	Informal	35. <i>C. selloana</i>	Germiston, Gauteng	Anonymous 2
	Informal	36. <i>C. jubata</i>	Germiston, Gauteng	Anonymous 2
	Formal	37. <i>C. selloana</i>	Pretoria, Gauteng	Anonymous 4
	Formal	38. <i>C. jubata</i>	Pretoria, Gauteng	Anonymous 4
	Formal	39. <i>C. selloana</i>	Online, website	Anonymous 5
	Formal	40. <i>C. selloana</i>	Germiston, Gauteng	Anonymous 6
	Formal	41. <i>C. jubata</i>	Germiston, Gauteng	Anonymous 6

For a control of testing seed viability and germination success, an alternative grass species was used as there are no commercially sold seeds of *Cortaderia* in South Africa. Lemongrass, *Cymbopogon citratus* (DC.) Stapf., acted as a control for experiments because it was commercially sold under the brand MayFord and, therefore, ensured to be viable. In addition, *C. citratus* has seeds similar in size to *Cortaderia*, is also a tall-statured grass and germinates under the same temperatures as *Cortaderia* (Francisco et al., 2011).

The seeds of all inflorescences were removed from the panicles using a sieve with 0.5 cm holes and stored at room temperature in seed envelopes. As in other experiments for the *Cortaderia* genus, the seeds were not stored longer than one year (Stanton and DiTomaso, 2004; Drewitz and DiTomaso, 2004). The viability of seed collected from each plant was assessed through three methods: using a stain specific for testing the viability of embryos in seeds (tetrazolium test); radicle protrusion in vitro in a controlled growth chamber (rapid germination); and seedling emergence in greenhouse conditions (germination in greenhouse).

4.2.2. Seed germination trials and data collection

4.2.2.1. Tetrazolium tests

To test viability, ten seeds per plant sampled (Table 4.2.1) were soaked in distilled water for 24 hours, then soaked in a 1 % solution of 2,3,5 tri-phenyl tetrazolium chloride (TZ) for 24 hours. The seeds were then examined using a dissecting microscope to observe staining. The seeds were considered viable if the entire embryo was stained red and the endosperm remained unstained (Figure 4.2.2.1). The seeds were considered non-viable if the embryo did not stain, only a part of the embryo stained, the stain was light pink, or the endosperm stained red in addition to or instead of the embryo (Drewitz et al., 2004). Ten replicates of ten seeds from the control species were used for comparison to the seeds of the two *Cortaderia* species.



Figure 4.2.2.1: (A) A viable and (B) non-viable *Cortaderia* seed under a microscope after treatment with tetrazolium stain.

4.2.2.2. *Rapid germination in a growth chamber*

For the rapid germination tests, 20 seeds per plant, including the control, were placed in petri dishes on top of a disc of Munktell Filtrak™ paper saturated with 5 ml of distilled water. The petri dishes were replicated three times (n = 60 seeds per plant) and placed in an *in vitro* PROLAB incubator. The temperature was set at 27 °C and water was added to the dishes in 2 ml increments as needed to keep the filter papers moist. Seeds were considered germinated when the radicle was clearly visible (Figure 4.2.2.2; Domènech and Vilà, 2008), and germination was recorded daily until all seeds stopped, and germinated seeds were removed from the petri dishes.



Figure 4.2.2.2: Laboratory monitoring of rapid germination in a petri dish (9 cm diameter) incubated in a growth chamber, showing the developed radicles from seeds of *Cortaderia selloana*.

4.2.2.3. Germination in a greenhouse

Germination pots (ranging from 8 – 18 cm) with drainage holes at the bottom were half-filled with culterra potting soil, and the seeds were buried at the surface of the soil in each pot (Figure 4.2.2.3A). For each plant, three pots (replicates), with 15 seeds per pot, including the control, were established (n = 129 pots). Germination pots were placed in a greenhouse following a randomised complete block design at the University of the Free State, Qwaqwa campus. The pots were re-randomised every two days to avoid greenhouse position effects. The temperature was set at 27°C. Pots were watered daily with 50 ml of distilled water. Germination was also monitored and recorded daily, until seeds stopped germinating, after the first seedling was observed. Seeds were considered germinated when the leaf emergence was clearly visible but were not removed from the pots (Figure 4.2.2.3B).



Figure 4.2.2.3A: Complete block design of the germination pots in a greenhouse at the University of the Free State, Qwaqwa campus



Figure 4.2.2.3B: Leaf emergence indicating germination of *Cortaderia* seeds.

4.2.3. Data analysis

All statistical analyses were performed using IBM SPSS version 29. For the tetrazolium test, the number of stained seeds was observed under a dissecting microscope and recorded as the proportion of viable seeds for each plant for each of the three species. The proportion data were arcsine-squareroot transformed and tested for normality using Shapiro Wilk's Normality test. The data for comparing species was not normally distributed ($P = 0.03$) and thus a Kruskal Wallis H-test with pairwise comparison post-hoc tests with Bonferreni correction was used to test for significant differences between species. The species were treated as the predictor (independent) variable and the response (dependant) variable was the transformed proportion of viable seed. After transforming the data and testing for normality as described above, the data for comparing the source (cultivated, naturalised, formal and informally traded inflorescences) was normally distributed ($P = 0.118$) and thus compared using Levene's test for homogeneity of variance (variances were equal, $P > 0.05$), and then a one-way ANOVA with Tukey HSD post-hoc.

For germination success in the growth chamber, the daily average germination success was calculated from the three replicates for each inflorescence, and accumulative average and standard error proportion of seeds germinated over all inflorescences of each species or source (cultivated, naturalised, formally and informally traded) plotted over time. Then the averaged overall proportions of germinated seeds per inflorescence were compared statistically. The proportion data were arcsine-squareroot transformed and tested for normality using Shapiro Wilk's Normality test. The data for comparing species and source (cultivated, naturalised, formally and informally traded) were not normally distributed (Species: $P = 0.020$; Source: $P = 0.044$) and thus non-parametric statistical tests were performed on these data. The species/ source was treated as the predictor (independent) variable and the response (dependent) variable was the transformed proportion of germinated seed using Kruskal-Wallis H-test with pairwise comparison post-hoc test with Bonferreni correction to test for significant differences.

For germination success in the greenhouse, the daily average germination success was calculated from the three replicates for each inflorescence, and accumulative average and standard error proportion of seeds germinated over all inflorescences of each species or source (cultivated, naturalised, formally and informally traded) plotted over time. Then the averaged overall proportions of germinated seeds per inflorescence were compared statistically. The proportion data were arcsine-squareroot transformed and tested for normality using Shapiro Wilk's Normality test. The data for comparing species and source (cultivated, naturalised, formally and informally traded) were not normally distributed (Species: $P < 0.001$; Source: $P < 0.001$) and thus non-parametric statistical tests were performed on these data. The species/ source was treated as the predictor (independent) variable and the response (dependent) variable was the transformed proportion of germinated seed, compared using a Kruskal-Wallis H-test with pairwise comparison post-hoc tests with Bonferreni correction to test for significant differences.

4.3. Results

Inflorescences of *Cortaderia* were collected across the nine provinces of South Africa. However, some inflorescences did not have seeds, or the seeds were immature and

could not be used for germination tests. Timing to find matured seeds still attached on the inflorescences is very narrow. Seeds of *C. jubata* are mature from late February to early March, while *C. selloana* seeds are mature from late March to early April. The short period to find mature seeds for each species resulted in a low number of seeds being collected. Overall, 73 inflorescences were collected from naturalised populations and 11 from cultivated populations. However, only 24 and four had mature seeds that could be used for germination, respectively. For traded populations, 19 inflorescences were bought from traders and 13 had mature seeds, including both formally and informally traded inflorescences (Appendix B).

4.3.1. *Tetrazolium* tests

The control (*C. citratus*) had an average of 89 % seed viability while *C. jubata* and *C. selloana* had an average of 54.28 % and 71.66 % seed viability, respectively. Seed viability differed significantly among species ($H = 7.387$; $df = 2, 48$; $P = 0.025$) with seed viability of the control significantly higher compared to *C. jubata* ($P = 0.020$) but not significantly different to *C. selloana* ($P = 0.493$) (Figure 4.3.1). There was no significant difference in the average seed viability between *C. selloana* and *C. jubata* ($P = 0.277$). Seed viability differed significantly among source ($F_{3,37} = 4.904$; $df = 39$; $P = 0.006$); with cultivated and naturalised *Cortaderia* inflorescences having a significantly higher average seed viability (80 % and 64.17 %, respectively) compared to the formally traded *Cortaderia* inflorescences (20 %) but not significantly different to the informally traded inflorescences (42.5 %) (Figure 4.3.2). The average seed viability of seeds from cultivated and naturalised *Cortaderia* inflorescences significantly differed to that of formally traded inflorescences ($P = 0.022$ and $P = 0.018$, respectively). There was no statistical difference in the average seed viability of cultivated and naturalised inflorescences ($P = 0.788$) and formal and informally traded inflorescences ($P = 0.626$).

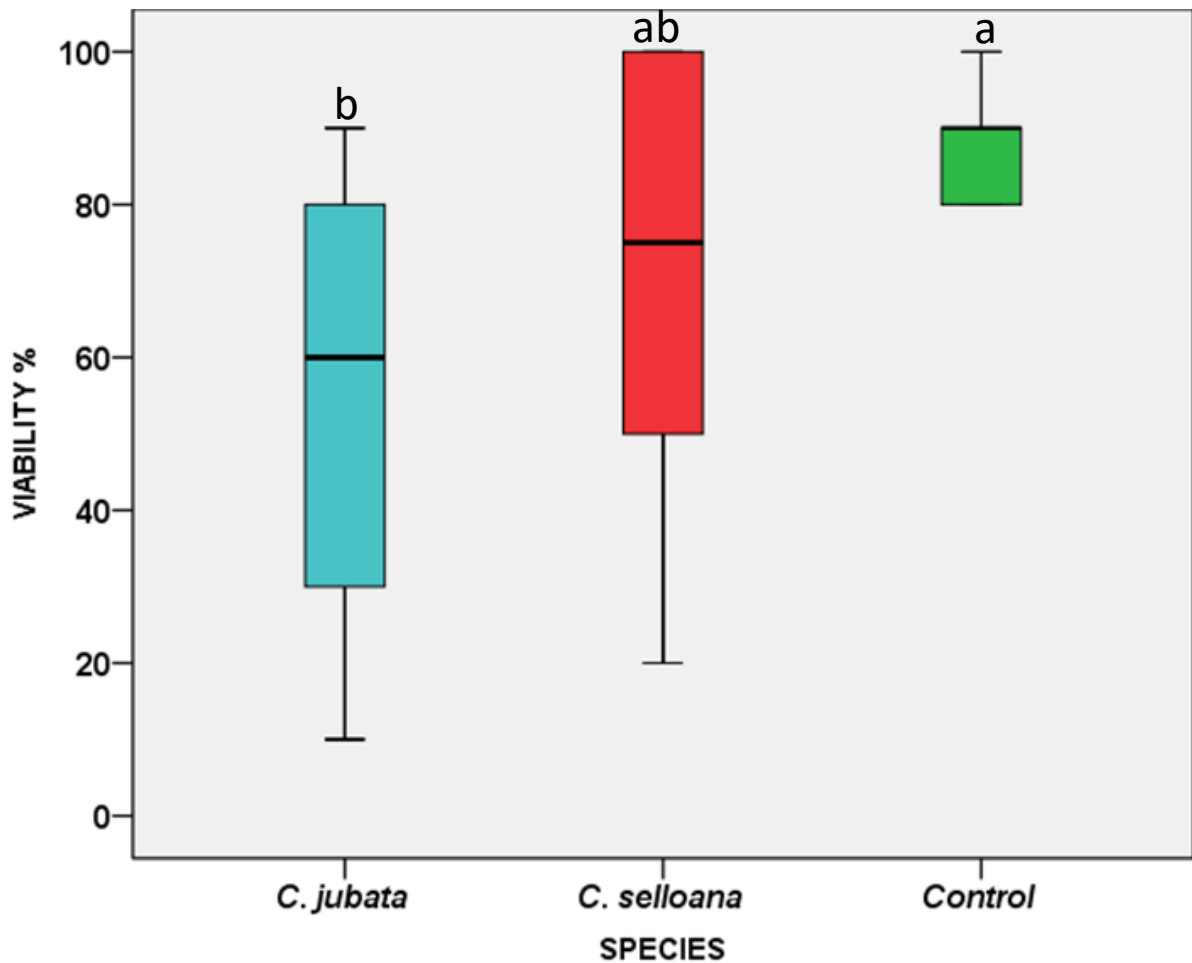


Figure 4.3.1: Comparison of seed viability following tetrazolium staining of two *Cortaderia* species (*C. jubata* and *C. selloana*) present in South Africa, in comparison to a commercially available grass, *Cymbopogon citratus* (Control). The dark black line represents the median, edges of the boxes represent interquartile range, and whiskers represent minimum and maximum values. Seed viability was compared using a Kruskal Wallis Test followed by a pairwise comparison posthoc test with a Bonferroni correction ($P = 0.025$); different letters above the bars represent significant differences.

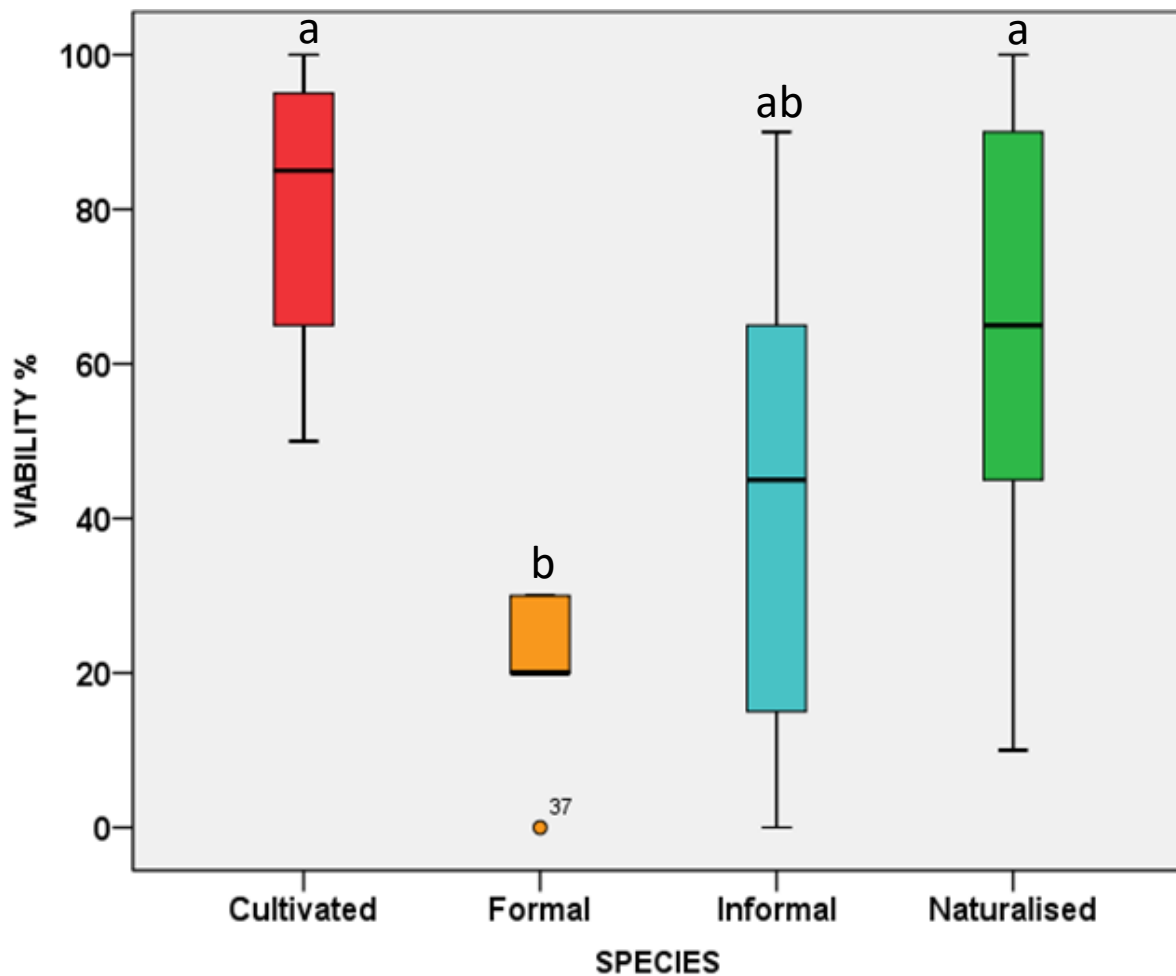


Figure 4.3.2: Comparison of seed viability of the cultivated, naturalised, formally and informally traded *Cortaderia* species in South Africa. The dark black line represents the median, edges of the boxes represent interquartile range, and whiskers represent minimum and maximum values. Seed viability was compared using an Analysis of Variance followed by a Tukey HSD posthoc test ($P = 0.006$); different letters above the bars represent significant differences.

4.3.2. Rapid germination in a growth chamber

For rapid germination, the control (*C. citratus*) started germinating on day three while the two *Cortaderia* species started germinating on day four, and all seeds of all species stopped germinating after 44 days (Figure 4.3.3). The control had an average \pm SE of 93.33 ± 3.33 % seed germination while *C. jubata* and *C. selloana* had an average of 52.62 ± 9.55 and 68.89 ± 4.45 %, respectively. Average germination success differed significantly among species ($H = 8.086$; $df = 2$; $P = 0.018$), with average germination

success of the control significantly higher compared to *C. jubata* ($P = 0.015$) and *C. selloana* ($P = 0.041$), but there was no statistical difference between the two *Cortaderia* species ($P = 1.00$) (Figure 4.3.3). Cultivated and naturalised *Cortaderia* populations had an average of 59.58 ± 6.46 and 65.69 ± 2.72 % germination success, respectively, while formal and informally traded *Cortaderia* populations had a germination success of 25.00 ± 5.60 and 28.75 ± 4.89 %, respectively, with germination success differing significantly among the different sources ($H = 23.030$ $df = 3$; $P < 0.001$; Figure 4.3.4). The average seed germination from naturalised *Cortaderia* populations was significantly higher compared to the formal ($P = 0.003$) and informally traded *Cortaderia* populations ($P = 0.001$). There was no statistical difference between cultivated and naturalised ($P = 1.00$), informally traded ($P = 0.293$) and formally traded *Cortaderia* populations ($P = 0.286$). Formal and informally traded *Cortaderia* populations were also not significantly different ($P = 1.00$).

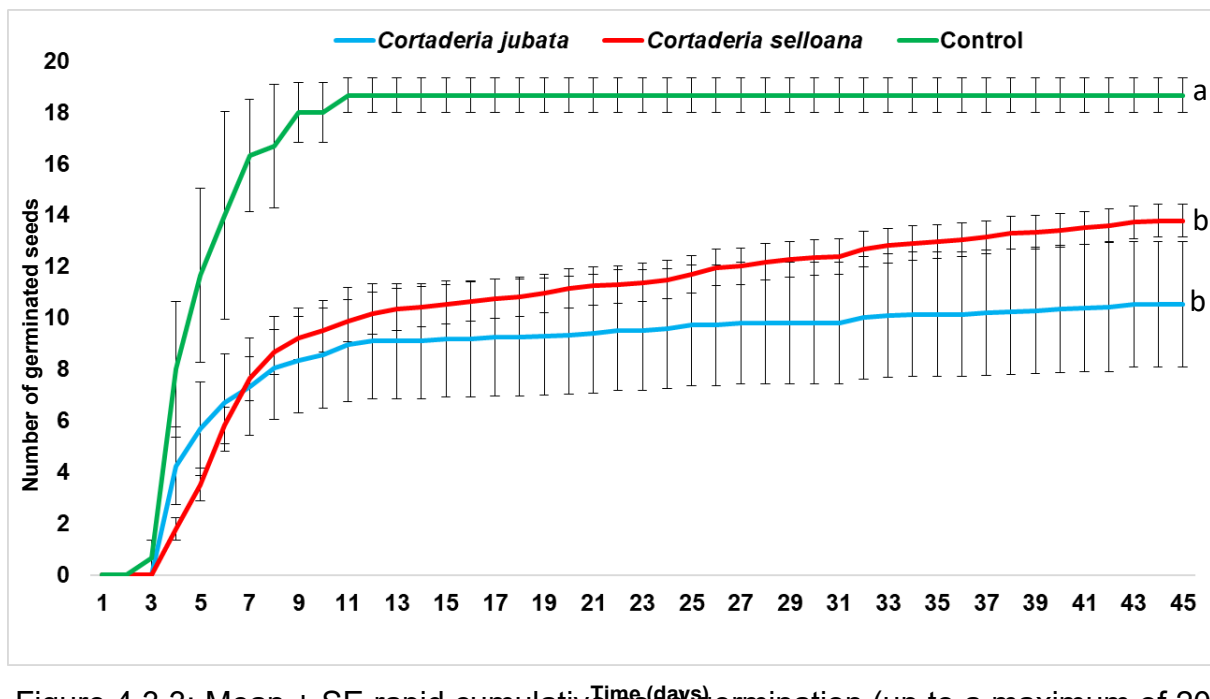


Figure 4.3.3: Mean \pm SE rapid cumulative seed germination (up to a maximum of 20 seeds) of *Cortaderia jubata* and *C. selloana* present in South Africa, in comparison to seeds of *Cymbopogon citratus* (control). Germination rate was compared using a Kruskal Wallis Test followed by a pairwise comparison posthoc test with a bonferroni correction ($P = 0.018$); different letters on the side represent significant differences.

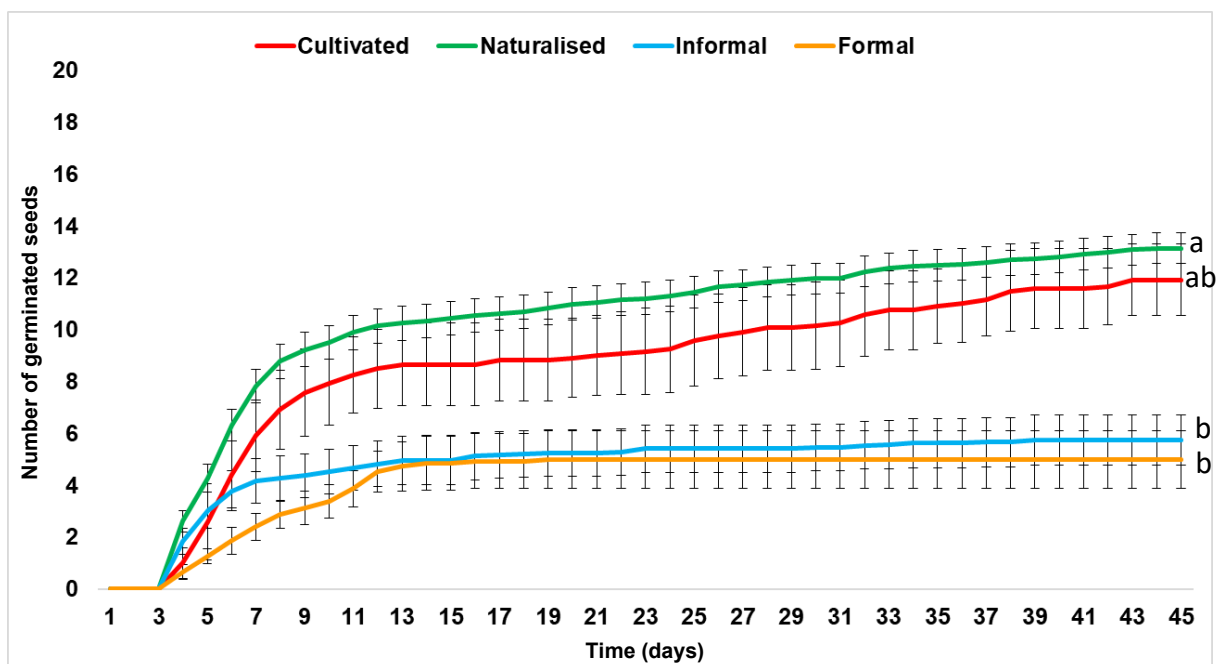


Figure 4.3.4: Mean \pm SE rapid cumulative seed germination (up to a maximum of 20 seeds) of cultivated, naturalised, formally and informally traded inflorescences of *Cortaderia* in South Africa. Germination rate was compared using a Kruskal Wallis Test followed by a pairwise comparison with a Bonferroni correction ($P < 0.001$); different letters on the side represent significant differences.

4.3.3. Germination in a greenhouse

For germination trials under greenhouse conditions, *C. citratus* (control) started germinating on day six while the two *Cortaderia* species started germinating on day seven. All seeds of the control, *C. jubata* and *C. selloana* stopped germinating after 11, 26 and 29 days, respectively. The control had an average of 48.89 ± 5.88 % seed germination while *C. jubata* and *C. selloana* had an average of 62.54 ± 11.83 % and 79.15 ± 5.56 %, respectively. The seed germination success was statistically similar for all three species ($H = 5.575$; $df = 2$; $P = 0.062$; Figure 4.3.5). Cultivated and naturalised *Cortaderia* populations had 78.89 ± 6.45 and 74.35 ± 2.75 % seed germination, respectively, while formal and informally traded *Cortaderia* populations had a germination success of 5.33 ± 1.81 and 35.56 ± 5.48 %, respectively. Germination success differed significantly among sources ($H = 19.841$; $df = 3$; $P < 0.001$). The average seed germination from cultivated *Cortaderia* populations was

significantly higher compared to the formally ($P = 0.002$) and informally traded *Cortaderia* populations ($P = 0.007$). There was no statistical difference between cultivated and naturalised ($P = 1.00$), informally traded ($P = 0.254$) and formally traded *Cortaderia* populations ($P = 0.080$). Formal and informally traded *Cortaderia* populations were also not significantly different ($P = 1.00$).

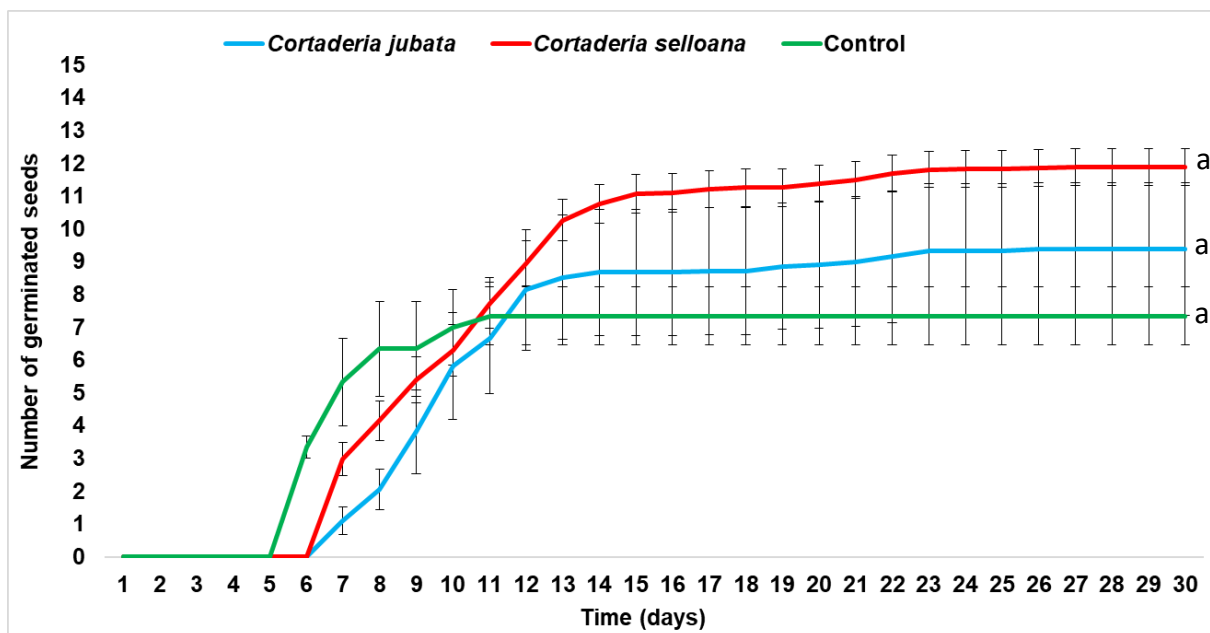


Figure 4.3.5: Mean \pm SE cumulative seed germination (in a greenhouse, up to a maximum of 15 seeds) of *Cortaderia jubata* and *C. selloana* present in South Africa, in comparison to seeds of *Cymbopogon citratus* (control). Germination rate was compared using a Kruskal Wallis Test followed by a pairwise comparison posthoc test with a Bonferroni correction ($P = 0.062$); different letters on the side represent significant differences.

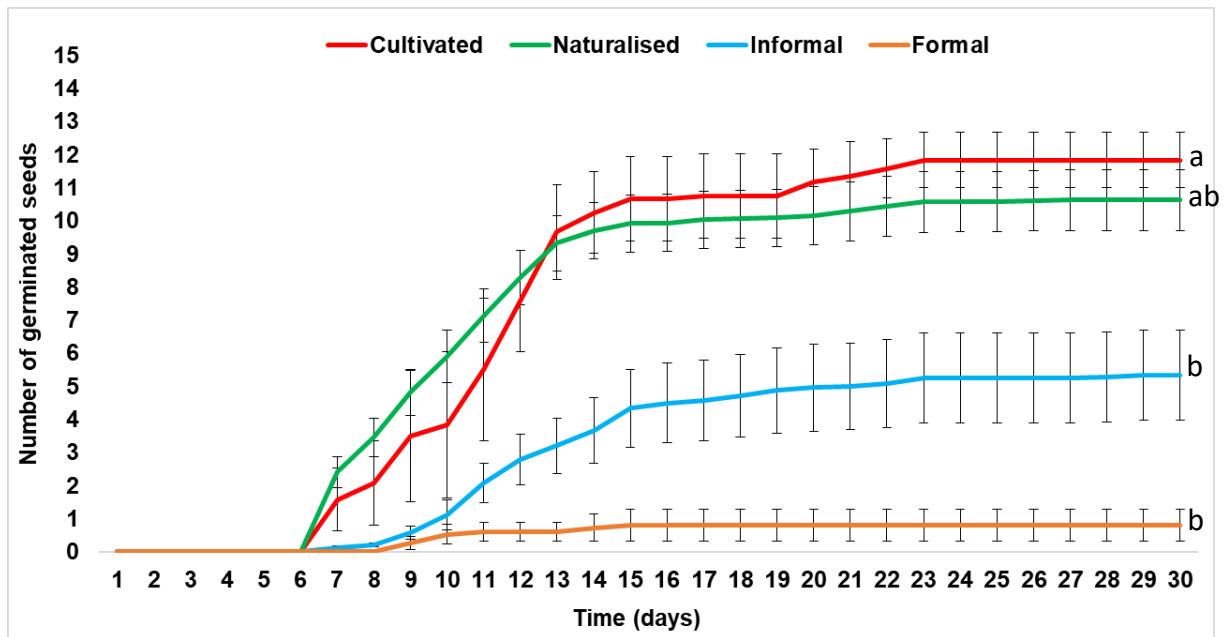


Figure 4.3.6: Mean \pm SE cumulative seed germination (in a greenhouse, up to a maximum of 15 seeds) of cultivated, naturalised, formally and informally traded inflorescences of *Cortaderia* in South Africa. Germination rate was compared using a Kruskal Wallis Test followed by a pairwise comparison posthoc test with a Bonferroni correction ($P < 0.001$); different letters on the side represent significant differences.

4.4. Discussion

Overall, the seed viability and germination success of *C. selloana* was higher than that of *C. jubata* for all three experimental methods, suggesting a higher potential for spread in South Africa. Cultivated and naturalised *Cortaderia* populations showed higher seed viability and germination success than the formally and informally traded *Cortaderia* across all three experimental methods. Moreover, 25 % of the seeds of *C. jubata* and *C. selloana* only germinated after several weeks from the start of germination experiments, suggesting that these species have a staggered germination strategy. Lastly, an average of 69.24, 70.02, 32.16 and 15.17 % seeds from cultivated, naturalised, informally and formally traded populations, respectively, germinated, indicating that the threat of *Cortaderia* spreading is not only from wind-dispersed seeds from naturalised populations but from trade as well.

Based on these results, seed viability and germination success of *C. selloana* is higher than that of *C. jubata* under different germination methods, likely indicating greater invasive potential for *C. selloana*, which supports studies reporting on successful invaders having increased germination success (Rejmanek and Richardson, 1996; Gioria and Pyšek, 2017). Also, this finding may provide an explanation for its more widespread distribution in South Africa compared to *C. jubata*. The role of germination traits as determinants of species invasiveness indicates that 'germination success/rate' is positively associated with the 'establishment/spread' and/or 'abundance/impact' of invasive species (Colautti et al., 2006). A study by Bacchetta et al. (2010) found *C. selloana* seeds germinated at a variety of incubation temperatures (i.e., 15 °C, 20 °C, 25 °C, 30 °C). Lázaro-Lobo et al. (2024a) showed that the minimum temperature for *C. selloana* to germinate is 10 °C, showing a high tolerance for low temperatures, which might also contribute to its high germination and invasion. This observation together with diverse environmental conditions in South Africa leads to the conclusion that *C. selloana* has high invasion potential. In contrast, *C. jubata* occurs mainly to the northern areas of the country and is spreading by producing wind dispersed seeds, of which only 20 to 30 % germinate when exposed to light (Drewitz and DiTomaso, 2004). In addition, *C. jubata* seeds do not persist under natural conditions after six months (Drewitz and DiTomaso, 2004).

Populations of *C. jubata* consist of entirely female plants that produce seeds asexually, resulting in seeds that are genetically identical to the parent plant (Stanton and DiTomaso, 2004). Of the total seeds produced, only 20 to 30 % readily germinate when exposed to light and under a temperature range similar to coastal environments (Drewitz and DiTomaso, 2004). A study by Drewitz and DiTomaso (2004) found no significant differences between the percentages of germinable and viable seeds, indicating that *C. jubata* does not have primary dormancy. Roldão et al. (2024) studied the morphological and reproductive traits in female and hermaphrodite plants of *C. selloana* and found significant differences regarding reproductive traits of female and hermaphrodite plants but no significant differences in morphological traits. Their results also found that female plants are largely responsible for the dispersal of the species, while hermaphrodite plants primarily serve as pollen donors, which might explain the germination success of *Cortaderia* species in South Africa.

Until recently, sterile cultivars of *Cortaderia* were permitted to be sold in nurseries. As such, cultivated plants in gardens were expected to have zero to very little germination, as it was assumed they were grown from sterile cultivars while naturalised populations were expected to have viable seeds as they are self-sustaining populations that likely would have had to have established from seeds due to a lack of intentional planting. However, there was no evidence of complete sterility in cultivated populations. Cultivated plants, collected from gardens, were found to have viable seeds suggesting that if these plants were bought from nurseries, it is unlikely that the cultivar was sterile. Hulme et al. (2018) and Van Kleunen et al. (2018) have shown that the introduction of alien plants as ornamentals in the horticulture industry is a major pathway for the introduction of IAPs globally. Results from these previous studies and the current study shows that the plant trade presents a route into South Africa for alien species and a potential mechanism for their spread within the country.

Formally traded seeds had lower average viability and germination (20, 25, 6.67 %) compared to the informally traded inflorescences (42.5, 28.75, 35.56 %) across triphenyl tetrazolium stain, growth chamber, and greenhouse, respectively. This suggests that the informal trade of *Cortaderia* inflorescences is an important pathway for the spread of these species in South Africa. Formal traders often indicated that they are aware of the problem of *Cortaderia* invasions in the country. Therefore, some

traders outline that they use sterilising techniques such as bleaching methods to prevent them from propagating or spreading (Bloom Space, 2024; Happy Home, 2024). Furthermore, formal traders generally preserve flowers and keep them past their flowering season. Therefore, most seeds are likely to be lost during transportation and out of season storage. In contrast, informal traders do not take such measures to treat the seeds (T. Mbele, pers. observ.). They generally collect from naturalised populations and sell them directly, only during the flowering period. The window period to find mature seeds on inflorescences is very short and seeds are easily blown by the wind, hence, seeds do not stay on inflorescences for long (T. Mbele, pers. observ.). According to Roldão et al. (2024), seeds of female plants are mature for 3 – 4 weeks from the onset of seed development and are dispersed by wind up to 4 months, but timings are influenced by weather conditions. Therefore, this could explain why informal trade is more likely to be spreading viable seeds. Lastly, one of the main issues that came up during conversations with informal traders was that they are not aware of the legislation forbidding them from selling pampas grass and thus were not aware of not complying with legislation informing trade of these species (T. Mbele, pers. observ.). Roldão et al. (2023), when studying the public perceptions about invasive *Cortaderia* in Portugal and Spain, also found that few people were aware of the legislation that limits its use. Therefore, it is recommended that information on legislation be shared with traders to ensure they are aware of the threats of *Cortaderia* and what native alternatives could be used to trade instead to protect their livelihoods.

4.5. Conclusion

Overall, some *Cortaderia* inflorescences had viable seeds within the flowering season in both naturalised and traded populations. This study established that *C. selloana* is potentially more invasive than *C. jubata* and that the informal trade of inflorescences is an important pathway for the spread of *Cortaderia*. However, more seeds are needed to conclusively determine if this pattern is true, and further investigation is warranted to confirm these findings. Moreover, this study found that informal traders need to be made aware of the current legislation prohibiting them from selling *Cortaderia*. Discovering this pathway of spread has important implications for the management of these alien species. Management should focus on enforcing legislation to stop the pathway of spread through trade, particularly during the short flowering season. Also, to reduce further spread, greater monitoring and cooperation with the informal trade for better management is proposed. Creating public awareness of the current legislation is also suggested, as well as the risks of *Cortaderia* invasions.

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Chapter 5: Dissertation discussion, conclusion and recommendations

This dissertation contains two experimental studies and two risk analyses reports (Appendix C) with the aim to investigate and understand the invasion risk posed by pampas grass in South Africa. The purpose of this study was to confirm which *Cortaderia* species are present in South Africa, ensure that there are no cryptic species and to understand their introduction history, and thus, guide a potential future biocontrol programme. In addition, it sought to determine the prevalence of sterility and, whether or not the trade of inflorescences is potentially fuelling new invasions. This dissertation also provides the necessary evidence for the regulation of *Cortaderia* species in the country using the Risk Analysis for Alien Taxa (RAAT) framework.

The genetic study (chapter 3) confirmed the presence of two *Cortaderia* species occurring in South Africa, *C. jubata* and *C. selloana*. All *C. jubata* plants present in South Africa are a single clone as evidenced by the lack of genetic variability within the species and restricted to the northern areas of the country. *Cortaderia selloana* was found to be genetically diverse. However, there was no distinction between cultivated and naturalised populations, suggesting that all plants likely came from the same source. Lastly, this study provided evidence that morphological assessments only based on inflorescence colour are not always accurate to distinguish the two species. It is therefore likely that non-experts who have previously contributed to recording their distribution based on this feature may have misidentified plants, possibly leading to inaccurate estimates of geographic distribution. These findings suggest that there have not been multiple introductions of *Cortaderia* into South Africa. Therefore, it is recommended that there is strict enforcement of the laws to prevent the horticultural trade from introducing new cultivars or lineages.

The germination trials (chapter 4) provided evidence that not all traded *Cortaderia* inflorescences are sterile. It also determined that *C. selloana* populations are more widely distributed and potentially more invasive than *C. jubata*. *Cortaderia selloana* has higher seed viability and germination than *C. jubata*, showing greater potential for invasiveness. Seed germination of *C. selloana* is reduced with decreasing temperatures and significantly enhanced with increasing temperatures (Lázaro-Lobo et al., 2024a). Therefore, climate change may be a future challenge to control the dispersal of this species. According to studies by Tarabon et al. (2008) and Liendo et

al. (2023), as global temperatures continue to rise, *C. selloana* is predicted to expand its distribution range in the forthcoming decades. This study also uncovered that the floristic trade could be fuelling new invasions of *Cortaderia* species in South Africa. It was apparent that most traders, especially informal, are not aware of the legislation that forbids them from selling pampas grass. Therefore, it is recommended that traders are made aware of the current legislation through awareness campaigns and provided with pamphlets that outline all the laws regarding trade of pampas grass in South Africa.

Risk analysis is a formal, evidence-based process to analyse the risk of a particular hazard of invasive species to a certain area or situation (Kumschick et al., 2020). In South Africa, the purpose of risk analyses is to more accurately classify alien species under National Regulations, to prevent the importation of species with a high potential for invasion and to determine if there is a need for a change of status for already-listed species (Kumschick et al., 2020). In addition, Risk Analysis for Alien Taxa is an important decision-support tool for the management of biological invasions (Kumschick et al., 2020). The invasive status of *Cortaderia* species in South Africa according to the risk analysis framework was explored. Both *C. jubata* and *C. selloana* had a high-risk score with medium ease of management. Nkuna et al. (2018) also assessed environmental and socio-economic impacts of selected alien grasses occurring in South Africa and found *C. selloana* to have the highest overall impact score. The risk analyses recommend all *Cortaderia* species (including “sterile” cultivars) to be listed under category 1b of the NEM:BA A&IS Regulations and biological control options to be explored (Appendix C).

To control populations of invasive plants, biocontrol by natural enemies has been implemented worldwide (Van Driesche and Bellows, 2012; Heimpel and Mils, 2017). However, no biological control agents have been intentionally released on *Cortaderia* to date (Winston et al., 2024). New Zealand has started a programme to develop biocontrol agents for both *C. jubata* and *C. selloana* and identified two potential biocontrol agents, *Ustilago quitensis* Lagerh. and *Sacchasydne subandina* Remes Lenicov and Rossi (Hayes, 2014), which are currently in the host specificity testing stages. Moreover, another potential natural enemy of *C. selloana*, *Spanolepis selloanae* Gagné, a flower-predating fly, was found in northwestern Spain (Fagúndez et al., 2021). Lázaro-Lobo et al. (2024a) also found *S. selloanae* widely distributed

across their study area in the northern Spain. This biocontrol agent feeds and damages seeds of *C. selloana* with an average of 74 % of inflorescences being damaged in Spain and is now in the host specificity testing stages (Fagúndez et al., 2021). Female flower development experiments on *C. selloana* predated on by *S. selloanae* revealed that only an average of 11.5 % of female flowers produce mature seeds, 75.3 % of which germinate, and the rest are aborted or destroyed by *S. selloanae* (Almeida et al., 2024).

Biocontrol agents are species-specific and now that *Cortaderia* species present in South Africa have been confirmed, these results can be used to guide biological control of these species in South Africa. The results of this dissertation indicated that *C. jubata* consists of a single genetic clone and that there is low genetic diversity for both species suggesting that they may be appropriate species for biocontrol. The occurrence of a single genetic clone, as detected for *C. jubata* in this study, greatly simplifies assignment of invasive plants to specific source populations in the native range and thus substantially narrows the regions to be searched for natural enemies. Further studies should focus on gathering baseline information for the development of a biocontrol programme on *Cortaderia* species in South Africa.

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Appendices

Appendix A: Sites where *Cortaderia* species' leaf samples were collected across South Africa.

Table 3.1 Plant identity, province, location, population size, land use and geographic coordinates for DNA samples of collected *Cortaderia* species in South Africa.

Plant ID	Province	Site location	Population size (1-5, 6-10, 10-20, >20)	Land use	GPS coordinates (latitude; longitude)
1. FS-LDYBRND-C.s_1	Free State	Ladybrand	>20	Golf Resort	-29.2006; 27.4635
2. FS-LDYBRND-C.s_1	Free State	Ladybrand	>20	Golf Resort	-29.2008; 27.4635
3. FS-LDYBRND-C.s_3	Free State	Ladybrand	>20	Golf Resort	-29.201; 27.4634
4. FS-LDYBRND-C.s_4	Free State	Ladybrand	>20	Golf Resort	-29.2012; 27.4632
5. FS-LDYBRND-C.s_5	Free State	Ladybrand	>20	Golf Resort	-29.2013; 27.4632
6. FS-LDYBRND-C.s_6	Free State	Ladybrand	>20	Golf Resort	-29.2015; 27.4631
7. FS-LDYBRND-C.s_7	Free State	Ladybrand	>20	Golf Resort	-29.2021; 27.4629
8. FS-LDYBRND-C.s_8	Free State	Ladybrand	>20	Golf Resort	-29.2023; 27.4628
9. FS-BLTFNTN-C.s	Free State	Builtfontein	1-5	Home garden	-28.285; 26.15
10. NW-DLYRVL-C.s	North West	Delareyville	1-5	Home garden	-26.686; 25.452
11. NC-KHTH-C.s_1	Northern Cape	Khathu	>20	Road side	-27.712; 23.053
12. NC-KHTH-C.s_2	Northern Cape	Khathu	>20	Road side	-27.713; 23.055
13. NC-KHTH-C.s_3	Northern Cape	Khathu	>20	Road side	-27.713; 23.054
14. NC-KHTH-C.s_4	Northern Cape	Khathu	>20	Road side	-27.715; 23.058
15. NC-KHTH-C.s_5	Northern Cape	Khathu	>20	Road side	-27.717; 23.056
16. NC-KHTH-C.s_6	Northern Cape	Khathu	>20	Road side	-27.718; 23.056
17. NC-KHTH-C.s_7	Northern Cape	Khathu	>20	Road side	-27.713; 23.056
18. NC-KHTH-C.s_8	Northern Cape	Khathu	>20	Road side	-27.714836; 23.053667

19. NC-KHTH-C.s_9	Northern Cape	Khathu	>20	Road side	-27.714889; 23.053703
20. NC-KHTH-C.s_10	Northern Cape	Khathu	>20	Road side	-27.714956; 23.053758
21. NC-KHTH-C.s_11	Northern Cape	Khathu	>20	Road side	-27.714811; 23.053622
22. NC-KHTH-C.s_12	Northern Cape	Khathu	>20	Road side	-27.714861; 23.05375
23. NC-KHTH-C.s_13	Northern Cape	Khathu	>20	Road side	-27.715019; 23.053086
24. NC-KHTH-C.s_14	Northern Cape	Khathu	>20	Road side	-27.715139; 23.053136
25. NW-GRTTNG-C.s_1	North West	Great Taung	1-5	Church	-27.211; 24.094
26. NW-GRTTNG-C.s_2	North West	Great Taung	1-5	Church	-27.211; 24.093
27. NC-KHTH-C.j_1	Northern Cape	Khathu	>20	Road side	-27.712; 23.053
28. NC-KHTH-C.j_2	Northern Cape	Khathu	>20	Road side	-27.715; 23.054
29. NC-KHTH-C.j_3	Northern Cape	Khathu	>20	Road side	-27.713; 23.054
30. NC-KHTH-C.j_4	Northern Cape	Khathu	>20	Road side	-27.715; 23.053
31. NC-KHTH-C.j_5	Northern Cape	Khathu	>20	Road side	-27.717; 23.056
32. NC-KHTH-C.j_6	Northern Cape	Khathu	>20	Road side	-27.713; 23.052
33. NC-KHTH-C.j_7	Northern Cape	Khathu	>20	Road side	-27.714961; 23.053131
34. NC-KHTH-C.j_8	Northern Cape	Khathu	>20	Road side	-27.714917; 23.053719
35. NC-DNLSKL-C.j	Northern Cape	Danielskuil	>20	River	-28.192; 23.549
36. NC-DNLSKL-Unknown_1	Northern Cape	Danielskuil	>20	River	-28.184944; 23.544292
37. NC-DNLSKL-Unknown_2	Northern Cape	Danielskuil	>20	River	-28.185192; 23.544525
38. NC-DNLSKL-Unknown_3	Northern Cape	Danielskuil	>20	River	-28.185347; 23.544756
39. NC-DNLSKL-Unknown_4	Northern Cape	Danielskuil	>20	River	-28.185597; 23.545192
40. NC-DNLSKL-Unknown_5	Northern Cape	Danielskuil	>20	River	-28.185839; 23.545508
41. NC-DNLSKL-Unknown_6	Northern Cape	Danielskuil	>20	River	-28.184539; 23.543628
42. NC-DNLSKL-Unknown_7	Northern Cape	Danielskuil	>20	River	-28.184425; 23.543414
43. FS-HRRSMTH-C.s_1	Free State	Harrismith	1-5	Home garden	-28.259722; 29.121389
44. FS-HRRSMTH-C.s_2	Free State	Harrismith	1-5	Home garden	-28.259444; 29.121111

45. FS-HRRSMTH-C.s_3	Free State	Harrismith	1-5	Home garden	-28.259444; 29.120833
46. FS-HRRSMTH-C.s_4	Free State	Harrismith	1-5	Home garden	-28.276667; 29.143333
47. FS-HRRSMTH-C.s_5	Free State	Harrismith	1-5	Home garden	-28.2774333; 29.1437016
48. FS-HRRSMTH-C.s_6	Free State	Harrismith	1-5	Home garden	-28.277845; 29.144205
49. FS-HRRSMTH-C.s_7	Free State	Harrismith	1-5	Home garden	-28.2773366; 29.1434583
50. FS-HRRSMTH_C.j	Free State	Harrismith	1-5	Home garden	-28.093611; 29.121389
51. GP-JHNSBG-C.j	Gauteng	Johannesburg	10-20	Natural park	-26.153; 27.9823
52. GP-JHNSBG-C.s_1	Gauteng	Johannesburg	10-20	Natural park	-26.153; 27.9825
53. GP-JHNSBG-C.s_2	Gauteng	Johannesburg	10-20	Natural park	-26.1889; 27.9562
54. GP-JHNSBG-C.s_3	Gauteng	Johannesburg	10-20	Road side	-26.1709; 27.9023
55. GP-JHNSBG-C.s_4	Gauteng	Johannesburg	10-20	Road side	-26.1246; 28.0091
56. GP-JHNSBG-C.s_5	Gauteng	Johannesburg	10-20	Road side	-26.1312; 27.9116
57. WC-DBNVL-C.s_1	Western Cape	Durbanville	1-5	Natural park	-33.86025; 18.62273
58. WC-DBNVL-C.s_2	Western Cape	Durbanville	6-10	Green belt	-33.82522; 18.63819
59. WC-DBNVL-C.s_3	Western Cape	Durbanville	6-10	Green belt	-33.82531; 18.63817
60. WC-SMNTWN-C.s	Western Cape	Simonstown	1-5	Veld	-34.19717 ; 18.42119
61. WC-STLNBSCH-C.s	Western Cape	Stellenbosch	6-10	Road edge	-33.94922; 18.81586
62. WC-TK-C.s_1	Western Cape	Tokai	>20	Natural park	-34.05405; 18.43164
63. WC-TK-C.s_2	Western Cape	Tokai	>20	Natural park	-34.05452; 18.43205
64. WC-TK-C.s_3	Western Cape	Tokai	>20	Natural park	-34.05468; 18.43231
65. WC-TK-C.s_4	Western Cape	Tokai	>20	Natural park	-34.05481; 18.43293
66. WC-TK-C.s_5	Western Cape	Tokai	>20	Natural park	-34.05474; 18.43303
67. WC-TK-C.s_6	Western Cape	Tokai	>20	Natural park	-34.05452; 18.43303
68. WC-TK-C.s_7	Western Cape	Tokai	>20	Natural park	-34.05495; 18.43393
69. WC-TK-C.s_8	Western Cape	Tokai	>20	Natural park	-34.05502; 18.43367
70. WC-TK-C.s_9	Western Cape	Tokai	>20	Natural park	-34.05515; 18.43339

71. WC-SPR-C.s_1	Western Cape	Spier	>20	Railway edge	-33.96316; 18.79722
72. WC-SPR-C.s_2	Western Cape	Spier	>20	Railway edge	-33.96323; 18.79717
73. FS-CLRNC-C.s_1	Free State	Clarens	1-5	Home garden	-28.5132216; 28.4206066
74. FS-CLRNC-C.s_2	Free State	Clarens	1-5	Home garden	-28.513705; 28.421085
75. FS-CLRNC-C.s_3	Free State	Clarens	1-5	Home garden	-28.502397; 28.419231
76. KZN-KLF-C.s	KwaZulu-Natal	Kloof	1-5	Road side	-29.7806583; 30.8249666
77. WC-BV Mun-C.s	Western Cape	Breede Valley Municipality	1-5	Road side	-33.892945; 19.4490633
78. FS-BTHLHM-C.s_1	Free State	Bethlehem	5-10	Road side	-28.239717; 28.29105
79. FS-BTHLHM-C.s_2	Free State	Bethlehem	5-10	Road side	-28.239883; 28.32613
80. EC-PE-C.s_1	Eastern Cape	Port Elizabeth	10-20	Road side	-33.929816; 25.555201
81. EC-PE-C.s_2	Eastern Cape	Port Elizabeth	10-20	Road side	-33.929818; 25.555199
82. EC-PE-C.s_3	Eastern Cape	Port Elizabeth	10-20	Road side	-33.929821; 25.555205
83. EC-PE-C.s_4	Eastern Cape	Port Elizabeth	10-20	Road side	-33.929816; 25.555204
84. KZN- UNDBG-C.s	KwaZulu-Natal	Underberg	1-5	River	-29.751815; 29.2958433
85. FS-QGSFNTN-C.s	Free State	Quaggasfontein	1-5	Home garden	-30.780203; 24.817397
86. FS-BLMFNTN-C.s_1	Free State	Bloemfontein	1-5	Home garden	-29.0814; 26.158556
87. FS-BLMFNTN-C.s_2	Free State	Bloemfontein	1-5	University	-29.111175; 26.185478
88. FS-BLMFNTN-C.s_3	Free State	Bloemfontein	>20	Museum	-29.100617; 26.219439
89. FS-BLMFNTN-C.s_4	Free State	Bloemfontein	>20	Museum	-29.102639; 26.219306
90. FS-BLMFNTN-C.s_5	Free State	Bloemfontein	>20	Museum	-29.100681; 26.219192
91. FS-BLMFNTN-C.s_6	Free State	Bloemfontein	>20	Museum	-29.100683; 26.219125
92. FS-BLMFNTN-C.s_7	Free State	Bloemfontein	>20	Museum	-29.100703; 26.219075
93. FS-BLMFNTN-C.s_8	Free State	Bloemfontein	>20	Museum	-29.100625; 26.219131
94. FS-BLMFNTN-C.s_9	Free State	Bloemfontein	>20	Museum	-29.100614; 26.219236
95. FS-BLMFNTN-C.s_10	Free State	Bloemfontein	>20	Museum	-29.100625; 26.219283
96. FS-BLMFNTN-C.s_11	Free State	Bloemfontein	1-5	Home garden	-29.063717; 26.177203

97. FS-MRQRD-C.s	Free State	Marquard	1-5	Home garden	-28.6608698; 27.4329934
98. MP-GN-C.j	Mpumalanga	Great Nigel	>20	Road side	-26.415167; 28.457778
99. MP-GN-C.s	Mpumalanga	Great Nigel	>20	Road side	-26.415389; 28.415789
100. MP-MLHLN-C.j	Mpumalanga	N12, Emalahleni	>20	Road side	-26.017111; 28.967722
101. MP-MLHLN-C.s	Mpumalanga	N12, Emalahleni	>20	Road side	-26.017111; 28.966972
102. MP-OGIES-C.j	Mpumalanga	Ogies	1-5	Road side	-26.050556; 29.053889
103. MP-MDBRG-C.s	Mpumalanga	N4 after Middleburg		Road side	-25.837139; 29.710778
104. MP-MKHZN-C.	Mpumalanga	Emakhazeni		Road side	-25.6075; 29.993056
105. MP-MLHLN-C.j 1	Mpumalanga	Emalahleni		Road side	-25.878944; 29.243722
106. MP-MLHLN-C.j 2	Mpumalanga	Emalahleni		Road side	-25.879028; 29.2435
107. MP-MLHLN-C.j 3	Mpumalanga	Emalahleni		Road side	-25.878528; 29.242222
108. MP-MLHLN-C.j 4	Mpumalanga	Emalahleni		Road side	-25.892833; 29.230472
109. MP-MLHLN-C.s 1	Mpumalanga	Emalahleni		Road side	-25.878583; 29.242361
110. MP-MLHLN-C.s 2	Mpumalanga	Emalahleni		Road side	-25.878583; 29.242778
111. MP-MLHLN-C.s 3	Mpumalanga	Emalahleni		Road side	-25.878361; 29.242417
112. MP-MLHLN-C.s 4	Mpumalanga	Emalahleni		Road side	-25.957111; 29.256111
113. MP-MLHLN-C.s 5	Mpumalanga	Emalahleni		Road side	-25.975778; 29.219583
114. MP-MLHLN-C.s 6	Mpumalanga	Emalahleni		Road side	-25.995777; 29.219799
115. LIM-HNSTBRG-C.j 1	Limpopo	Haenertsburg		Road side	-23.940889; 29.930472
116. LIM-HNSTBRG-C.s	Limpopo	Haenertsburg		Road side	-23.940861; 29.929833
117. LIM-HNSTBRG-C.j 2	Limpopo	Haenertsburg		Road side	-23.939361; 29.937028
118. LIM-MGBKLF-C.s 1	Limpopo	Magoebaskloof		Road side	-23.925; 29.961333
119. LIM-MGBKLF-C.s 2	Limpopo	Magoebaskloof		Road side	-23.873556; 29.994722

Appendix B: The *Cortaderia* inflorescences collected from naturalised populations and bought from commercial and informal traders in South Africa.

Naturalised	Species	Town/ supplier	Source/ trade	Seeds
	<i>C. jubata</i>	Cradock, Eastern Cape	Naturalised	No seeds
	<i>C. selloana</i>	Cradock, Eastern Cape	Naturalised	No seeds
	<i>C. selloana</i>	Cradock, Eastern Cape	Naturalised	No seeds
	<i>C. selloana</i>	Cradock, Eastern Cape	Naturalised	Seeds
	<i>C. selloana</i>	Cradock, Eastern Cape	Naturalised	No seeds
	<i>C. selloana</i>	Cradock, Eastern Cape	Naturalised	No seeds
	<i>C. jubata</i>	Cradock, Eastern Cape	Naturalised	No seeds
	<i>C. selloana</i>	Cradock, Eastern Cape	Naturalised	No seeds
	<i>C. selloana</i>	Cradock, Eastern Cape	Naturalised	No seeds
	<i>C. jubata</i>	Cradock, Eastern Cape	Naturalised	No seeds
	<i>C. selloana</i>	Cradock, Eastern Cape	Naturalised	No seeds
	<i>C. selloana</i>	Cradock, Eastern Cape	Naturalised	No seeds
	<i>C. jubata</i>	Cradock, Eastern Cape	Naturalised	No seeds
	<i>C. jubata</i>	Cradock, Eastern Cape	Naturalised	No seeds
	<i>C. jubata</i>	Cradock, Eastern Cape	Naturalised	No seeds
	<i>C. jubata</i>	Port Elizabeth, Eastern Cape	Naturalised	No seeds
	<i>C. selloana</i>	Port Elizabeth, Eastern Cape	Naturalised	Seeds
	<i>C. selloana</i>	Port Elizabeth, Eastern Cape	Naturalised	Seeds
	<i>C. jubata</i>	Port Elizabeth, Eastern Cape	Naturalised	No seeds
	<i>C. selloana</i>	Port Elizabeth, Eastern Cape	Naturalised	No seeds
	<i>C. selloana</i>	Port Elizabeth, Eastern Cape	Naturalised	No seeds
	<i>C. selloana</i>	Port Elizabeth, Eastern Cape	Naturalised	No seeds
	<i>C. jubata</i>	Port Elizabeth, Eastern Cape	Naturalised	No seeds
	<i>C. selloana</i>	Port Elizabeth, Eastern Cape	Naturalised	Seeds


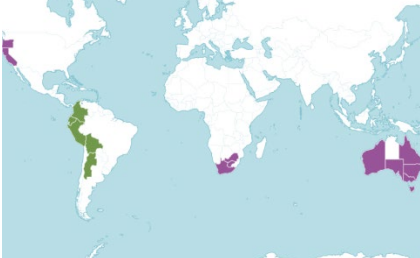
	<i>C. jubata</i>	Port Elizabeth, Eastern Cape	Naturalised	No seeds
	<i>C. selloana</i>	Port Elizabeth, Eastern Cape	Naturalised	No seeds
	<i>C. selloana</i>	Port Elizabeth, Eastern Cape	Naturalised	Seeds
	<i>C. jubata</i>	Johannesburg, Gauteng	Naturalised	Seeds
	<i>C. selloana</i>	Johannesburg, Gauteng	Naturalised	No seeds
	<i>C. jubata</i>	Johannesburg, Gauteng	Naturalised	Seeds
	<i>C. jubata</i>	Johannesburg, Gauteng	Naturalised	No seeds
	<i>C. selloana</i>	Johannesburg, Gauteng	Naturalised	Seeds
	<i>C. selloana</i>	Johannesburg, Gauteng	Naturalised	Seeds
	<i>C. selloana</i>	Johannesburg, Gauteng	Naturalised	Seeds
	<i>C. selloana</i>	Johannesburg, Gauteng	Naturalised	No seeds
	<i>C. selloana</i>	Johannesburg, Gauteng	Naturalised	No seeds
	<i>C. selloana</i>	Johannesburg, Gauteng	Naturalised	No seeds
	<i>C. selloana</i>	Johannesburg, Gauteng	Naturalised	No seeds
	<i>C. selloana</i>	Johannesburg, Gauteng	Naturalised	Seeds
	<i>C. selloana</i>	Johannesburg, Gauteng	Naturalised	Seeds
	<i>C. selloana</i>	Johannesburg, Gauteng	Naturalised	No seeds
	<i>C. jubata</i>	Johannesburg, Gauteng	Naturalised	Seeds
	<i>C. jubata</i>	Johannesburg, Gauteng	Naturalised	Seeds
	<i>C. jubata</i>	Johannesburg, Gauteng	Naturalised	Seeds
	<i>C. selloana</i>	Johannesburg, Gauteng	Naturalised	No seeds
	<i>C. selloana</i>	Johannesburg, Gauteng	Naturalised	Seeds
	<i>C. selloana</i>	Johannesburg, Gauteng	Naturalised	Seeds
	<i>C. selloana</i>	Johannesburg, Gauteng	Naturalised	Seeds
	<i>C. selloana</i>	Johannesburg, Gauteng	Naturalised	No seeds
	<i>C. jubata</i>	Johannesburg, Gauteng	Naturalised	Seeds
	<i>C. selloana</i>	Johannesburg, Gauteng	Naturalised	No seeds
	<i>C. jubata</i>	Johannesburg, Gauteng	Naturalised	Seeds
	<i>C. selloana</i>	Johannesburg, Gauteng	Naturalised	Seeds
	<i>C. selloana</i>	Johannesburg, Gauteng	Naturalised	Seeds
	<i>C. selloana</i>	Bultfontein, Free State	Cultivated	No seeds
	<i>C. selloana</i>	Bultfontein, Free State	Cultivated	No seeds
	<i>C. selloana</i>	Ladybrand, Free State	Naturalised	Seeds
	<i>C. selloana</i>	Ladybrand, Free State	Naturalised	Seeds
	<i>C. selloana</i>	Ladybrand, Free State	Naturalised	Seeds

	<i>C. selloana</i>	Ladybrand, Free State	Naturalised	No seeds
	<i>C. selloana</i>	Ladybrand, Free State	Naturalised	Seeds
	<i>C. selloana</i>	Ladybrand, Free State	Naturalised	Seeds
	<i>C. selloana</i>	Ladybrand, Free State	Naturalised	Seeds
	<i>C. selloana</i>	Ladybrand, Free State	Naturalised	No seeds
	<i>C. selloana</i>	Clarens, Free State	Cultivated	No seeds
	<i>C. selloana</i>	Clarens, Free State	Cultivated	No seeds
	<i>C. selloana</i>	Durbanville, Western Cape	Naturalised	No seeds
	<i>C. selloana</i>	Durbanville, Western Cape	Naturalised	No seeds
	<i>C. selloana</i>	Durbanville, Western Cape	Naturalised	No seeds
	<i>C. selloana</i>	Simonstown, Western Cape	Naturalised	No seeds
	<i>C. selloana</i>	Stellenbosch, Western Cape	Naturalised	No seeds
	<i>C. selloana</i>	Tokai, Western Cape	Naturalised	No seeds
	<i>C. selloana</i>	Tokai, Western Cape	Naturalised	No seeds
	<i>C. selloana</i>	Tokai, Western Cape	Naturalised	No seeds
	<i>C. selloana</i>	Tokai, Western Cape	Naturalised	No seeds
	<i>C. selloana</i>	Tokai, Western Cape	Naturalised	No seeds
	<i>C. selloana</i>	Tokai, Western Cape	Naturalised	No seeds
	<i>C. selloana</i>	Tokai, Western Cape	Naturalised	No seeds
	<i>C. selloana</i>	Tokai, Western Cape	Naturalised	No seeds
	<i>C. selloana</i>	Tokai, Western Cape	Naturalised	No seeds
	<i>C. selloana</i>	Tokai, Western Cape	Naturalised	No seeds
	<i>C. selloana</i>	Tokai, Western Cape	Naturalised	No seeds
	<i>C. selloana</i>	Tokai, Western Cape	Naturalised	No seeds
	<i>C. selloana</i>	Tokai, Western Cape	Naturalised	No seeds
	<i>C. selloana</i>	Spier, Western Cape	Naturalised	No seeds
	<i>C. selloana</i>	Spier, Western Cape	Naturalised	No seeds
	<i>C. selloana</i>	Bloemfontein, Free State	Cultivated	No seeds
	<i>C. selloana</i>	Bloemfontein, Free State	Cultivated	No seeds
	<i>C. selloana</i>	Bloemfontein, Free State	Cultivated	No seeds
Traded	<i>C. selloana</i>	Anonymous 1	Informal	Seeds

<i>C. jubata</i>	Anonymous 1	Informal	Seeds
<i>C. selloana</i>	Vendor 1	Informal	Seeds
<i>C. selloana</i>	Vendor 2	Informal	Seeds
<i>C. selloana</i>	Vendor 3	Informal	Seeds
<i>C. selloana</i>	Vendor 4	Informal	Seeds
<i>C. selloana</i>	Anonymous 2	Informal	Seeds
<i>C. jubata</i>	Anonymous 2	Informal	Seeds
<i>C. selloana</i>	Anonymous 3	Formal	No seeds
<i>C. selloana</i>	Anonymous 4	Formal	Seeds
<i>C. jubata</i>	Anonymous 4	Formal	Seeds
<i>C. selloana</i>	Anonymous 5	Formal	Seeds
<i>C. selloana</i>	Anonymous 6	Formal	Seeds
<i>C. jubata</i>	Anonymous 6	Formal	Seeds
<i>C. selloana</i>	Anonymous 7	Formal	No seeds
<i>C. selloana</i>	Anonymous 8	Informal	No seeds
<i>C. selloana</i>	Anonymous 9	Formal	No seeds
<i>C. selloana</i>	Anonymous 10	Formal	No seeds
<i>C. selloana</i>	Anonymous 11	Formal	No seeds

Appendix C: Risk analyses of *Cortaderia* species occurring in South Africa.

Risk Analysis Report: *Cortaderia jubata*

<p>Taxon: <i>Cortaderia jubata</i> (Lemoine) Stapf</p>	<p>Area: South Africa</p>
<p>Compiled by: Thembelihle J. Mbele</p>	<p>Approved by:</p>
<p>Picture of Taxon</p>  <p>Photo: T. Mokotjomela (Johannesburg, Gauteng, 09 January 2022).</p>	<p>Alien distribution map</p>  <p>Native range (green), Alien range (purple) Reference: POWO, 2024, '<i>Cortaderia jubata</i> (Lemoine) Stapf', viewed 03 December 2024, from https://powo.science.kew.org/taxon/urn:lsid:ipni.org:names:66302-2</p>
<p>Risk Assessment summary: <i>Cortaderia jubata</i> was introduced to South Africa as an ornamental, used as erosion control, and for mine-dump stabilisation. <i>Cortaderia jubata</i> is present in eight provinces and particularly problematic in Gauteng and Mpumalanga. <i>Cortaderia jubata</i> can produce seeds without pollination, which can spread via wind and water dispersal. Trade of <i>C. jubata</i> is banned in South Africa; however, informal trade is likely ongoing. <i>Cortaderia jubata</i> has Major environmental impacts as it suppresses the growth of neighbouring plants, disrupts ecological processes and destroys habitat for native fauna. <i>Cortaderia jubata</i> has Minor socio-economic impacts via abrasive leaves with sharp, cutting edges that can cause injury to humans and fluffy inflorescences that cause respiratory problems, especially to people with asthma.</p>	<p>Risk score: High</p>
<p>Management options summary: Management may be feasible in open habitats but can be complicated by occurrence in inaccessible areas such as high-altitude grasslands, rocky areas, coastal dunes, and sandy habitats. Early reproduction and the ability of plants to reproduce without fertilisation complicate management. Seeds do not, however, appear to survive for longer than a year. The benefits as an ornamental, soil erosion control and stabilising mine dumps are regarded as low as they can be replaced by native taxa or non-harmful aliens. Control methods include grazing, mechanical, and chemical control. <i>Ustilago</i> spp. are used as biocontrol in New Zealand and was shown to damage flower heads. No biological control agents have been released in South Africa.</p>	<p>Ease of management: Easy</p>
<p>Recommendations: Due to the widespread distribution of <i>C. jubata</i>, major impacts on biodiversity and some minor socio-economic impacts, the recommendation is: 1) to retain <i>C. jubata</i> (including all cultivars because they are genetically related and may have similar impacts) in category 1b; 2) all populations invading riparian areas should be targeted for removal; and 3) a proper molecular investigation on <i>C. jubata</i> present in South Africa should be done to determine similarity with the species in New Zealand to determine feasibility for developing biological control as a management solution. Furthermore, 4) it is recommended to update the nomenclature noting that there have been various proposals for reclassifying the taxon—it will be prudent to recheck this before updating any lists.</p>	<p>Listing under NEM:BA A&IS lists of 2020: 1b as '<i>Cortaderia jubata</i> (Lemoine ex Carrière) Stapf'</p> <p>Recommended listing category: 1b as '<i>Cortaderia jubata</i> (Lemoine) Stapf'</p>

Suggested citation: SANBI (unpublished) Risk analysis of *Cortaderia jubata* (Lemoine) Stapf for South Africa as per the risk analysis for alien taxa framework v1.2, approved by the South African Alien Species Risk Analysis Review Panel on 03 December 2024, pp 20, <http://dx.doi.org/10.5281/zenodo.14264679>

1. Background

BAC1 Name of assessor(s)	
Name of lead assessor	Thembelihle Mbele
Additional assessor (1)	
Additional assessor (2)	
BAC2 Contact details of assessor (s)	
Lead assessor	Organisational affiliation: South African National Biodiversity Institute (Directorate on Biodiversity Evidence)
	email: 2019434030@ufs4life.ac.za
	Phone: +2763 446 7124
Additional assessor (1)	Organisational affiliation:
	email:
	Phone:
Additional assessor (2)	Organisational affiliation:
	email:
	Phone:
BAC3 Name(s) and contact details of expert(s) consulted	
Expert (1)	Name: Dr Thabiso M Mokotjomela
	email: t.mokotjomela@sanbi.org.za
	Phone: +2773 324 6118
Expert (2)	Name:
	email:
	Phone:
Comments: Dr Thabiso M Mokotjomela assisted with biological and ecological concepts relating to the invasion of <i>C. jubata</i> ; undocumented occurrence records of the species in different provinces, provided corrections on the report; interpretation of scores and provided additional sources of information on the processes and mechanism of biological invasions.	
BAC4 Scientific name of Taxon under assessment	
Taxon name: <i>Cortaderia jubata</i>	Authority: (Lemoine) Stapf
Comments: <i>Cortaderia jubata</i> has an accepted taxonomic status (ITIS, 2024; SANBI 2016), although there are differences in the presentation of the authority. The version as presented in the ITIS is preferred here. However, the most recent revision of the genus treats <i>C. jubata</i> as a subspecies of <i>C. selloana</i> [<i>Cortaderia selloana</i> subsp. <i>jubata</i> (Lemoine) Testoni & Villamil] (Testoni & Linder 2017). As this proposal has not been adopted by any of the references consulted during the preparation of this risk analysis here nor implemented in the taxonomic backbones consulted (i.e., ITIS), <i>Cortaderia jubata</i> is considered as a valid species for the purposes of this risk analysis.	
References: Integrated Taxonomic Information System (ITIS), 2024, viewed 24 October 2023, from https://www.itis.gov/servlet/SingleRpt/SingleRpt?search_topic=TSN&search_value=501640#null South African National Biodiversity Institute (SANBI), 2016, 'Botanical Database of Southern Africa (BODATSA) [dataset]', viewed 22 October 2024, from https://posa.sanbi.org/sanbi/Explore Testoni, D., & Linder, H. P. 2017, 'Synoptic taxonomy of <i>Cortaderia</i> stapf (danthonioideae, poaceae)', <i>PhytoKeys</i> (76), 39. https://doi.org/10.3897/phytokeys.76.10808 .	
BAC5 Synonym(s) considered	
Synonyms: <i>Gynerium jubatum</i> Lemoine <i>Gynerium pygmaeum</i> Nees <i>Gynerium quila</i> var. <i>pygmaeum</i> Nees.	
Comments: There are three synonyms of <i>C. jubata</i> listed by ITIS (2022). This assessment considered all these synonyms in the literature search. However, no additional information was obtained through searching for these synonyms.	

References: Integrated Taxonomic Information System (ITIS), 2022, viewed 16 August 2022, from https://www.itis.gov/servlet/SingleRpt/SingleRpt#null .	
BAC6 Common name(s) considered	
Common names: pampas grass purple pampas grass Andean pampas grass selloa pampas grass	
Comments: There are four common names for <i>C. jubata</i> (ITIS 2022). Purple pampas grass is the most widely used common name for <i>C. jubata</i> (CABI 2022) and was therefore used in the literature search.	
References: Centre for Agriculture and Bioscience International (CABI), 2022, Invasive species compendium, viewed 16 August 2022, from https://www.cabi.org/isc/datasheet/113484 . Integrated Taxonomic Information System (ITIS), 2022, viewed 16 August 2022, from https://www.itis.gov/servlet/SingleRpt/SingleRpt#null .	
BAC7 What is the native range of the Taxon?	
Response: South America	Confidence: High
Comments: <i>Cortaderia jubata</i> is native to South America, occurring in the following countries: Argentina, Bolivia, Chile, Ecuador and Peru (Connor & Edgar 1974; Houliston & Goeke 2017; Stanton & DiTomaso 2004). See map in Appendix BAC7 for details.	
References: Connor, H.E. & Edgar, E., 1974, 'Names and types in <i>Cortaderia</i> Stapf (Graminae)', <i>Taxon</i> 23, 595-605. https://doi.org/10.2307/1218786 . Houliston, G.J. & Goeke, D.F., 2017, ' <i>Cortaderia</i> species in New Zealand: patterns of genetic variation in two widespread invasive species', <i>New Zealand Journal of Ecology</i> 41(1), 107-112. https://doi.org/10.20417/nzj ecol.41.13 . Stanton, A. E. & DiTomaso, J.M., 2004, 'Growth response of <i>Cortaderia selloana</i> and <i>Cortaderia jubata</i> (Poaceae) seedlings to temperature, light and water', <i>Madrone</i> 51(3), 312-321. https://www.jstor.org/stable/41425552 .	
BAC8 What is the global alien range of the Taxon?	
Response: Africa Europe North America Oceania	Confidence: High
Comments: <i>Cortaderia jubata</i> is present as an alien in 21 countries across five continents but is considered particularly problematic in Australia, South Africa, New Zealand and the United States (CABI 2022; Houliston & Goeke 2017; Robinson 1984). In the US, <i>C. jubata</i> is listed as a noxious weed in California, Hawaii and Oregon (USDA-ARS 2014). See map in Appendix BAC8 for details.	
References: Centre for Agriculture and Bioscience International (CABI), 2022, <i>Invasive species compendium</i> , viewed 16 August 2022, from https://www.cabi.org/isc/datasheet/113484 Houliston, G.J. & Goeke, D.F., 2017, ' <i>Cortaderia</i> species in New Zealand: patterns of genetic variation in two widespread invasive species', <i>New Zealand Journal of Ecology</i> 41(1), 107-112. https://doi.org/10.20417/nzj ecol.41.13 . Robinson, E.R., 1984, 'Naturalized species of <i>Cortaderia</i> (Poaceae) in Southern Africa', <i>South African Journal of Botany</i> 3, 343-346. https://doi.org/10.1016/S0022-4618(16)30023-7 . USDA-ARS, 2014, Germplasm Resources Information Network (GRIN). Online Database. Beltsville, Maryland, USA: National Germplasm Resources Laboratory. https://npgsweb.ars-grin.gov/gringlobal/taxon/taxonomysearch.aspx	
BAC9 Geographic scope = the Area under consideration	
Area of assessment: South Africa	
Comments: The geographic scope of this assessment is limited to South Africa.	
BAC10 Is the Taxon present in the Area?	
Response: Yes	Confidence: High

<p>Comments: Until 1982/83, it was assumed that only <i>C. selloana</i> was present in South Africa (Robinson 1984), however, field observations and examination of specimen housed at the National Herbarium (PRE) and Moss Herbarium (J) confirmed the presence of <i>C. jubata</i> in South Africa (Robinson 1984). <i>Cortaderia jubata</i> was introduced to South Africa and cultivated for ornamental purposes, for use in mine-dump stabilisation and erosion control and is reported to be present in all provinces except the North West province and is most problematic in the Gauteng and Mpumalanga provinces (Henderson 2020; Sutton et al. 2021).</p>		
<p>References: Henderson, L., 2020, <i>Invasive Species Plants in South Africa</i>, Plant Protection Research Institute Handbook 21, Agricultural Research Council, Department of Forestry, Fisheries and the Environment, South Africa. Robinson, E.R., 1984, 'Naturalized species of <i>Cortaderia</i> (Poaceae) in Southern Africa', <i>South African Journal of Botany</i> 3, 343-346. https://doi.org/10.1016/S0022-4618(16)30023-7. Sutton, G., Brownes, A., Visser, V., Mapaura, A. & Canavan K., 2021, 'Progress and prospects for the biological control of invasive alien grasses (Poaceae) in South Africa', <i>African Entomology</i> 29(3), 837-858, https://doi.org/10.4001/003.029.0837.</p>		
<p>BAC11 Availability of physical specimen</p>		
Response: Yes		Confidence in ID: High
<p>Herbarium or museum accession number: Physical specimens can be found at the Pretoria National Herbarium – PRE, accession number – 0037344, collected and identified by M.O. Ruth on the 16th of August 1958 (SANBI 2016). Herbarium – PRE, accession number 0976977, collected and identified by M.C. Lippmann on the 16th of September 1969 (SANBI 2016).</p>		
<p>References: South African National Biodiversity Institute (SANBI), 2016, 'Botanical Database of Southern Africa (BODATSA) [dataset]', viewed 22 October 2024, from https://posa.sanbi.org/sanbi/Explore</p>		
<p>BAC12 Is the <i>Taxon</i> native to the Area or part of the Area?</p>		
The <i>Taxon</i> is native to (part of) the Area.	No	Confidence: High
The <i>Taxon</i> is alien in (part of) the Area.	Yes	Confidence: High
<p>Comments: <i>Cortaderia jubata</i> is native to South America (Connor & Edgar 1974; Houliston & Goeke 2017; Stanton & DiTomaso 2004).</p>		
<p>References: Connor, H.E. & Edgar, E., 1974, 'Names and types in <i>Cortaderia</i> Stapf (Graminae)', <i>Taxon</i> 23, 595-605. https://doi.org/10.2307/1218786. Houliston, G.J. & Goeke, D.F., 2017, '<i>Cortaderia</i> species in New Zealand: patterns of genetic variation in two widespread invasive species', <i>New Zealand Journal of Ecology</i> 41(1), 107-112. https://doi.org/10.20417/nzj ecol.41.13. Stanton, A. E. & DiTomaso, J.M., 2004, 'Growth response of <i>Cortaderia selloana</i> and <i>Cortaderia jubata</i> (Poaceae) seedlings to temperature, light and water', <i>Madrono</i> 51(3), 312-321. https://www.jstor.org/stable/41425552.</p>		
<p>BAC13 What is the <i>Taxon</i>'s introduction status in the Area?</p>		
The <i>Taxon</i> is in cultivation/containment.	Yes	Confidence: High
The <i>Taxon</i> is present outside of cultivation/containment.	Yes	Confidence: High
The <i>Taxon</i> has established/naturalised.	Yes	Confidence: High
The <i>Taxon</i> is invasive.	Yes	Confidence: High
<p>Comments: <i>Cortaderia jubata</i> is cultivated for ornamental purposes, used in stabilisation of mine-dumps and erosion control (Henderson 2020). <i>Cortaderia jubata</i> is known to have escaped containment and has naturalised, established and become invasive (Robinson 1984).</p>		
<p>References: Henderson, L., 2020, <i>Invasive Species Plants in South Africa</i>, Plant Protection Research Institute Handbook 21, Agricultural Research Council, Department of Forestry, Fisheries and the Environment, South Africa. Robinson, E.R., 1984, 'Naturalized species of <i>Cortaderia</i> (Poaceae) in Southern Africa', <i>South African Journal of Botany</i> 3, 343-346. https://doi.org/10.1016/S0022-4618(16)30023-7.</p>		

BAC14 Primary (introduction) pathways		
Release	erosion control	Confidence: High
Escape	horticulture	Confidence: High
	ornamental purpose other than horticulture	Confidence: High
Contaminant	none	Confidence: Low
Stowaway	machinery/equipment	Confidence: Low
Corridor	interconnected waterways/basins/seas	Confidence: Medium
Unaided	natural dispersal across borders of invasive alien organisms	Confidence: High
<p>Comments: <i>Cortaderia jubata</i> was introduced to South Africa as an ornamental plant, for mine-dump stabilisation, and erosion control (CABI 2022; Henderson 2020). The seeds of <i>C. jubata</i> are light and dispersed by wind and water (Drewitz & DiTomaso 2004; Mokotjomela et al. 2022; Stanton & DiTomaso 2004). Additionally, seeds of <i>C. jubata</i> are spread by machinery and in garden waste (CABI 2022; Mokotjomela et al. 2022; Stanton & DiTomaso 2004). The presence of <i>C. jubata</i> in neighbouring countries (i.e., Eswatini and Lesotho – Henderson 2020; Mgidi et al. 2007) will make future unintentional introductions (via natural dispersal) likely.</p>		
<p>References:</p> <p>Centre for Agriculture and Bioscience International (CABI), 2022, <i>Invasive species compendium</i>, viewed 17 August 2022, from https://www.cabi.org/isc/datasheet/113484.</p> <p>Drewitz, J.J. & DiTomaso, J.M., 2004, 'Seed biology of jubatagrass (<i>Cortaderia jubata</i>)', <i>Weed Science</i> 52, 525-530. https://doi.org/10.1614/WS-03-081R.</p> <p>Henderson, L., 2020, <i>Invasive Species Plants in South Africa</i>, Plant Protection Research Institute Handbook 21, Agricultural Research Council, Department of Forestry, Fisheries and the Environment, South Africa.</p> <p>Mgidi, T.N., Le Maitre, D.C., Schonegevel, L., Nel, J.L., Rouget, M., & Richardson, D.M., 2007, 'Alien Plant Invasions-incorporating emerging invaders in regional prioritization: a pragmatic approach for Southern Africa', <i>Journal for Environmental Management</i> 84, 173-187. https://doi.org/10.1016/j.jenvman.2006.05.018.</p> <p>Mokotjomela, T.M., Nemurangoni, T., Mundalamo, T., Jaca, T. & Kuhudzai, A.G., 2022, 'The value of dumps sites for monitoring biological invasions in South Africa', <i>Biological Invasions</i> 24, 971-986. https://doi.org/10.1007/s10530-021-02683-5.</p> <p>Stanton, A. E., DiTomaso, J.M., 2004, 'Growth response of <i>Cortaderia selloana</i> and <i>Cortaderia jubata</i> (Poaceae) seedlings to temperature, light and water', <i>Madrono</i> 51(3), 312-321. https://www.jstor.org/stable/41425552.</p>		

2. Likelihood

LIK1 Likelihood of entry via unaided primary pathways	
Response: Present in the country (p = 1)	Confidence: High
<p>Rationale: <i>Cortaderia jubata</i> is present in the country. In terms of the likelihood of future introductions, <i>C. jubata</i> is present in two countries neighbouring South Africa (i.e., Eswatini and Lesotho - Henderson 2020; Mgidi et al. 2007). Moreover, <i>C. jubata</i> produce high quantities of small wind and water dispersed seeds (Drewitz & DiTomaso 2004; Parsons & Cuthbertson 2001). Therefore, it is fairly probable (p = 0.5) that <i>C. jubata</i> would re-enter South Africa through unaided pathways.</p>	
<p>References:</p> <p>Drewitz, J.J. & DiTomaso, J.M., 2004, 'Seed biology of jubatagrass (<i>Cortaderia jubata</i>)', <i>Weed Science</i> 52, 525-530. https://doi.org/10.1614/WS-03-081R.</p> <p>Henderson, L., 2020, <i>Invasive Species Plants in South Africa</i>, Plant Protection Research Institute Handbook 21, Agricultural Research Council, Department of Forestry, Fisheries and the Environment, South Africa.</p> <p>Mgidi, T.N., Le Maitre, D.C., Schonegevel, L., Nel, J.L., Rouget, M., & Richardson, D.M., 2007, 'Alien Plant Invasions-incorporating emerging invaders in regional prioritization: a pragmatic approach for Southern Africa', <i>Journal for Environmental Management</i> 84, 173-187. https://doi.org/10.1016/j.jenvman.2006.05.018.</p> <p>Parsons, W. T. & Cuthbertson, E.G., 2001, <i>Noxious weeds of Australia</i>, Inkata Press, Australia, 698 pp.</p>	

LIK2 Likelihood of entry via human aided primary pathways	
Response: Present in the country (p = 1)	Confidence: High
<p>Rationale: <i>Cortaderia jubata</i> is present in the country. In terms of the likelihood of future introductions, inflorescences of <i>C. jubata</i> are popular for home decorations and special events, hence <i>C. jubata</i> is still being sold through retail and informal trade in South Africa (House & Garden 2019; SA Weddings 2020). <i>Cortaderia jubata</i> could be intentionally brought or illegally imported into South Africa, particularly from neighbouring countries (e.g., Lesotho – Henderson 2020) where <i>C. jubata</i> is present and through online sales that deliver from other countries to South Africa. However, imports may be low given the current lack of commercial interest in <i>C. jubata</i> (EPPO 2018). Therefore, entry via human-aided pathways is fairly probable (p = 0.5).</p>	
<p>References:</p> <p>European and Mediterranean Plant Protection Organization (EPPO), 2018, 'Pest risk analysis for <i>Cortaderia jubata</i> EPPO, Paris. https://pra.eppo.int/prae19fd73e-0d29-4a86-917f-420d5b803121</p> <p>Henderson, L., 2020, <i>Invasive Species Plants in South Africa</i>, Plant Protection Research Institute Handbook 21, Agricultural Research Council, Department of Forestry, Fisheries and the Environment, South Africa.</p> <p>House & Garden, 2019, 'Trend alert: pampas grass', viewed 17 August 2023, from https://www.houseandgarden.co.za/design/trend-alert-pampas-grass-31056090.</p> <p>SA Weddings, 2018, '10 must-see floral weddings trends for 2018', viewed 17 August 2023, from https://www.saweddings.co.za/articles/inspiration-51/articles-interviews-55/10-must-see-floral-wedding-trends-for2018.</p>	

LIK3 Habitat suitability	
Response: Probable (p = 1)	Confidence: High
<p>Rationale: <i>Cortaderia jubata</i> grows on a variety of soils, is highly adaptable to various conditions, but easily establishes in wet, sandy soils without existing vegetation (DiTomaso et al. 2010; GISD 2022). <i>Cortaderia jubata</i> occurs along roadsides, coastal and grassland sites, and can survive in disturbed sites (e.g., recently felled and early-stage woodlands, waste deposits, swamps and wetlands) (CABI 2022; Parsons & Cuthbertson 2001). Germination of <i>C. jubata</i> requires sandy soils, ample moisture, and light and a temperature range of typical coastal environments (DiTomaso et al. 2010). The habitat conditions required for the growth and survival of <i>C. jubata</i> are met within South Africa (Henderson 2020; Mucina & Rutherford 2006).</p>	
<p>References:</p> <p>Centre for Agriculture and Bioscience International (CABI), 2022, <i>Invasive species compendium</i>, viewed 18 August 2022, from https://www.cabi.org/isc/datasheet/113484.</p>	

DiTomaso, J.M., Healy, E., Bell, C.E., Drewitz, J. & Stanton, A., 2010, 'Pampasgrass and Jubatagrass threaten California coastal habitats', *WEED Research & Information Center*. University of California.

Henderson, L., 2020, *Invasive Species Plants in South Africa*, Plant Protection Research Institute Handbook 21, Agricultural Research Council, Department of Forestry, Fisheries and the Environment, South Africa.

Global Invasive Species Database. 2022. Species profile: *Cortaderia jubata*. Downloaded from <http://www.iucngisd.org/gisd/species.php?sc=375> on 12-09-2022.

Mucina, L. & Rutherford, M.C., 2006, *The vegetation of South Africa, Lesotho and Swaziland, Strelitzia 19*, South African National Biodiversity Institute, Pretoria. www.sanbi.org/wp-content/uploads/2018/05/Strelitzia-19.pdf.

Parsons, W. T. & Cuthbertson, E. G., 2001, *Noxious weeds of Australia*, Inkata Press, Australia, 698 pp.

LIK4 Climate suitability

Response: Fairly probable (p = 0.5)

Confidence: Low

Rationale: *Cortaderia jubata* grows best in full sun with adequate water. However, because of the deep rooting system, *C. jubata* can also tolerate drought (CABI 2024). *Cortaderia jubata* does not do well under extreme weather conditions, such as winter frost, very hot summers, intense sunlight and moderate drought (DiTomaso et al. 2010; GISD 2022), but plants do not die under these conditions (GISD 2022). The Köppen-Geiger climate classification map produced by Beck et al. (2018) shows marginal climatic overlap (<20%) between the native range of *C. jubata* and South Africa. Therefore, the likelihood of *C. jubata* to thrive is fairly probable (p = 0.5) because the climatic conditions required for the growth and survival of *C. jubata* are met within South Africa. The confidence is scored as low because the information is inferred from a secondary source and not from a climatic suitability model.

References:

Beck, H.E., Zimmerman, N.E., McVicar, T.R., Vergopolan, N., Berg, A. & Wood, E.F., 2018, 'Present and future Köppen-Geiger climate classification maps at 1-km resolution', *Scientific Data* 5, 180214. <https://doi.org/10.1038/sdata.2018.214>.

California Invasive Plant Council (Cal-IPC), 2018, 'California Invasive Plant Inventory', Cal-IPC Publication 2006-2018, Berkeley, CA. from <https://www.cal-ipc.org/plants/inventory/>. Accessed on 8 November 2021.

Centre for Agriculture and Bioscience International (CABI), 2024, Invasive species compendium, viewed 11 January 2024, from <https://www.cabi.org/isc/datasheet/113484>.

DiTomaso, J.M., Healy, E., Bell, C.E., Drewitz, J. & Stanton, A., 2010, 'Pampasgrass and jubatagrass Threaten California Coastal Habitats', *WEED Research & Information Center*. University of California.

Global Invasive Species Database. 2022. Species profile: *Cortaderia jubata*. Downloaded from <http://www.iucngisd.org/gisd/species.php?sc=375> on 12-09-2022.

LIK5 Unaided secondary (dispersal) pathways

Response: Fairly probable (p = 0.5)

Confidence: High

Rationale: *Cortaderia jubata* produces considerable quantities of wind-dispersed seeds (up to 100 000 per flower head) (DiTomaso et al. 2010; Drewitz & DiTomaso 2004). Seeds are light and normally wind-dispersed but can also be dispersed by moving water (CABI 2022; Parsons & Cuthbertson 2001). Under windy conditions, seeds can be dispersed long distance, infesting areas within a 25 km radius (DiTomaso et al. 2010; Drewitz & DiTomaso 2004). Therefore, it is fairly probable (p = 0.5) that *C. jubata* will be dispersed via unaided secondary pathways.

References:

Centre for Agriculture and Bioscience International (CABI), 2022, *Invasive species compendium*, viewed 18 August 2022, from <https://www.cabi.org/isc/datasheet/113484>.

DiTomaso, J.M., Healy, E., Bell, C.E., Drewitz, J. & Stanton, A., 2010, 'Pampasgrass and jubatagrass Threaten California Coastal Habitats', *WEED Research & Information Center*. University of California.

Drewitz, J.J. & DiTomaso, J.M., 2004, 'Seed biology of jubatagrass (*Cortaderia jubata*)', *Weed Science*, 52, 525-530. <https://doi.org/10.1614/WS-03-081R>.

Parsons, W. T. & Cuthbertson, E. G., 2001, *Noxious weeds of Australia*, Inkata Press, Australia, 698 pp.

LIK6 Human aided secondary (dispersal) pathways

Response: Fairly probable (p = 1)	Confidence: High
<p>Rationale: The inflorescences of <i>C. jubata</i> are used for home decorations and special events (House & Garden 2020; SA Weddings 2020; Sutton et al. 2021). Therefore, <i>C. jubata</i> may be moved by people for these purposes. Also, due to high adaptability, disposed <i>C. jubata</i> at dumping sites can facilitate the establishment of new populations (Mokotjomela et al. 2022; Parsons & Cuthbertson 2001). According to Mokotjomela et al. (unpublished), <i>C. jubata</i> is currently sold as an ornamental in some nurseries in South Africa. However, the closely related species which is also present in South Africa, <i>C. selloana</i>, is far more common in the globalised commercial nursery trade and likely sold much more commonly as cut flowers. Moreover, because of inflorescence usage for decorations and as ornamentals, <i>C. jubata</i> is still sold through retail and informal trade (Mbele et al. 2023) and this informal trade may be the most important pathway for <i>C. jubata</i>, given its comparative minor status in the globalised nursery and cut flower trade. Therefore, it is fairly probable (p = 0.5) that <i>C. jubata</i> will be dispersed via human aided secondary pathways.</p>	
<p>References:</p> <p>House & Garden, 2019, 'Trend alert: pampas grass', viewed 17 August 2023, from https://www.houseandgarden.co.za/design/trend-alert-pampas-grass-31056090.</p> <p>Mbele, T.J., Steenhuisen S., & Canavan K., 2023, 'The invasive status of <i>Cortaderia</i> species in South Africa", Poster presentation presented on 06 July 2023 at the National Symposium on Biological Invasions 2023, https://doi.org/10.13140/RG.2.2.36267.41764.</p> <p>Mokotjomela, T.M., Nemurangoni, T., Mundalamo, T., Jaca, T. & Kuhudzai, A.G., 2022, 'The value of dumps sites for monitoring biological invasions in South Africa, <i>Biological Invasions</i> 24, 971-986. https://doi.org/10.1007/s10530-021-02683-5.</p> <p>Mokotjomela, T.M., Mbele T.J.& Vukeya L.R., (unpublished), 'Progress in the alien and invasive plant species' detection in Northern Cape, Free State and Eastern Cape provinces'.</p> <p>Parsons, W. T. & Cuthbertson, E. G., 2001, <i>Noxious weeds of Australia</i>, Inkata Press, Australia, 698 pp.</p> <p>SA Weddings, 2018, '10 must-see floral weddings trends for 2018', viewed 17 August 2023, from https://www.saweddings.co.za/articles/inspiration-51/articles-interviews-55/10-must-see-floral-wedding-trends-for2018.</p> <p>Sutton, G., Brownes, A., Visser, V., Mapaura, A. & Canavan K., 2021, 'Progress and prospects for the biological control of invasive alien grasses (Poaceae) in South Africa', <i>African Entomology</i> 29(3), 837-858, https://doi.org/10.4001/003.029.0837.</p>	

3. Consequences

CON1 Environmental impact	
CON1a: Competition	
Response: Major (MR)	Confidence: High
<p>Rationale: <i>Cortaderia jubata</i> forms dense stands of giant tussocks in wetter areas and competes with and displaces native ground cover, shrubs and ferns (CABI 2022; GISD 2022; EPPO 2018; PIER 2017). <i>Cortaderia jubata</i> suppresses the growth of neighbouring plants, disrupts ecological processes and destroys habitat for native fauna by colonising disturbed sites and quickly becoming dense (CABI 2023; Lambrinos 2000). Prolific seed production in <i>C. jubata</i>, rapid growth and accumulation of above and below-ground biomass allows <i>C. jubata</i> to acquire light, moisture and nutrients to the detriment of indigenous plant species (CABI 2023; Drewitz & DiTomaso 2004). In some locations in California U.S.A, invasion of <i>C. jubata</i> reduced plant species diversity, life form richness and altered arthropod and small mammal communities (Lambrinos 2000).</p>	
<p>References: Centre for Agriculture and Bioscience International (CABI), 2022, <i>Invasive species compendium</i>, viewed 18 August 2022, from https://www.cabi.org/isc/datasheet/113484. Drewitz, J.J. & DiTomaso, J.M., 2004, 'Seed biology of jubatagrass (<i>Cortaderia jubata</i>)', <i>Weed Science</i> 52, 525-530. https://doi.org/10.1614/WS-03-081R. European and Mediterranean Plant Protection Organization (EPPO), 2018, 'Pest risk analysis for <i>Cortaderia jubata</i> EPPO, Paris. https://pra.eppo.int/prae19fd73e-0d29-4a86-917f-420d5b803121 Global Invasive Species Database. 2022. Species profile: <i>Cortaderia jubata</i>. Downloaded from http://www.iucngisd.org/gisd/species.php?sc=375 on 12-09-2022. Lambrinos, J.G., 2000, 'The impact of the invasive alien grass <i>Cortaderia jubata</i> (Lemoine) Stapf on an endangered Mediterranean-type shrubland in California', <i>Diversity and Distributions</i> 6(5), 217-231. https://doi.org/10.1046/j.1472-4642.2000.00086.x. Pacific Island Ecosystem Risk (PIER), 2017, '<i>Cortaderia jubata</i>', viewed 03 July 2024, from http://www.hear.org/pier/wra/pacific/cortaderia_jubata_htmlwra.htm.</p>	
CON1b: Predation	
Response: Data Deficient (DD)	Confidence: High
<p>Rationale: <i>Cortaderia jubata</i> is a plant that is not predatory.</p>	
References:	
CON1c: Hybridisation	
Response: Data Deficient (DD)	Confidence: Low
<p>Rationale: There are no native <i>Cortaderia</i> species in South Africa, therefore, <i>C. jubata</i> does not hybridise with any native species. No information could be found to show that <i>C. selloana</i> and <i>C. jubata</i> hybridise.</p>	
References:	
CON1d: Transmission of disease	
Response: Data Deficient (DD)	Confidence: Low
<p>Rationale: There is no documented literature on <i>C. jubata</i> transmitting diseases.</p>	
References:	
CON1e: Parasitism	
Response: Data Deficient (DD)	Confidence: High
<p>Rationale: <i>Cortaderia jubata</i> is not a parasitic plant.</p>	
References:	
CON1f: Poisoning/toxicity	
Response: Data Deficient (DD)	Confidence: Low
<p>Rationale: <i>Cortaderia jubata</i> is not poisonous as animals can feed on it when the plant is still young while leaf edges are not sharp (NSW WeedWise 2022)</p>	
<p>References: NSW WeedWise, 2022, 'Common pampas grass (<i>Cortaderia selloana</i>)', viewed 22 August 2022, from https://weeds.dpi.nsw.gov.au/Weeds/Details/100.</p>	
CON1g: Bio-fouling or other direct physical disturbance	
Response: Data Deficient (DD)	Confidence: Low
<p>Rationale: There is no documented literature to support <i>C. jubata</i> biofouling or causing direct physical disturbance.</p>	

References:	
CON1h: Grazing/herbivory/browsing	
Response: Data Deficient (DD)	Confidence: High
Rationale: <i>Cortaderia jubata</i> is a plant and does not graze nor browse.	
References:	
CON1i: Chemical, physical or structural impact on ecosystem	
Response: Major (MR)	Confidence: High
Rationale: <i>Cortaderia jubata</i> alters the structure of invaded communities; reduces herbaceous community diversity and limits small mammal distribution and activity patterns (Blood 2001; Lambrinos 2000). <i>Cortaderia jubata</i> can also exclude most other ground flora and seriously impede over-storey regeneration (Muyt 2001). Flowering stalks of <i>C. jubata</i> produce large amounts of dry and flammable material which increase fire hazards (Bossard et al. 2000; DiTomaso 2000). During a fire, the large tussocks of <i>C. jubata</i> effectively insulate the growing meristem, making <i>C. jubata</i> resilient to fire (Lambrinos 2000).	
References:	
Blood, K., 2001, <i>Environmental weeds – a field guide for SE Australia</i> , CRC Weed Management Systems. CH Jerram & Associates, Australia.	
Bossard, C.C., Randall, J.M. & Houshovsky, M.C., 2000, <i>Invasive plants in California wildlands</i> , University of California, USA.	
DiTomaso, J., 2000, ' <i>Cortaderia selloana</i> ', In: Bossard, C.C., & Randall, J.M. (eds), <i>Invasive plants in California wildlands</i> , University of California Press, USA, 128-133.	
Lambrinos, J.G., 2000, 'The impact of the invasive alien grass <i>Cortaderia jubata</i> (Lemoine) Stapf on an endangered Mediterranean-type shrubland in California', <i>Diversity and Distributions</i> , 6(5), 217-231. https://doi.org/10.1046/j.1472-4642.2000.00086.x .	
Muyt, A., 2001, <i>Bush invaders of south-east Australia. A guide to the identification and control of environmental weeds found in south-east Australia</i> , R.G. & F.J. Richardson, Australia. https://www.cabdirect/abstract/20013109015 .	
CON1k: Indirect impacts through interactions with other species	
Response: Minimal Concern (MC)	Confidence: Medium
Rationale: <i>Cortaderia jubata</i> leaves are very abrasive with sharp and cutting edges, making it undesirable as food or shelter to birds and other wildlife as the leaves can cause physical harm to those animals (CABI 2023; Henderson 2020). Also, <i>C. jubata</i> seeds stick to fruits such as kiwifruit, seriously degrading fruit quality (GISD 2022).	
References:	
Centre for Agriculture and Bioscience International (CABI), 2023, <i>Invasive species compendium</i> , viewed 24 August 2023, from https://www.cabi.org/isc/datasheet/113484 .	
Global Invasive Species Database. 2022. Species profile: <i>Cortaderia jubata</i> . Downloaded from http://www.iucngisd.org/gisd/species.php?sc=375 on 12-09-2022.	
Henderson, L., 2020, <i>Invasive Species Plants in South Africa</i> , Plant Protection Research Institute Handbook 21, Agricultural Research Council, Department of Forestry, Fisheries and the Environment, South Africa.	
CON1 Maximum environmental impact	
Response: Major (MR)	Confidence: High
Rationale: <i>Cortaderia jubata</i> competes with and displaces native species, forming dense stands at some invaded sites replacing ground cover, shrubs, and ferns (EPPO 2018; GISD 2022; PIER 2017; Lambrinos 2000). <i>Cortaderia jubata</i> is responsible for the suppression of other species, disruption of ecological processes and destruction of habitats for native fauna and is able to colonise disturbed sites (CABI 2023; Lambrinos 2000). Accumulation of above and below-ground biomass allows <i>C. jubata</i> to outcompete other plants for light, moisture and nutrients (CABI 2023; Drewitz & DiTomaso 2004; Lambrinos 2000). Structure, species composition or regeneration of several sites with high conservation value are also affected by the establishment or invasion of <i>C. jubata</i> (DiTomaso et al. 2010; Lambrinos 2000). Reduced plant species diversity, life form richness and changes to community structure are all results of invasions by <i>C. jubata</i> (Blood 2001; Lambrinos 2000). Large quantities of dry matter produced by <i>C. jubata</i> pose a fire hazard, increasing the intensity of fires (Bossard et al. 2000; CABI 2023). <i>Cortaderia jubata</i> is resilient to fire because the large tussocks produced insulate the growing meristem during fire events (Lambrinos 2000).	

References:
 Blood, K., 2001, *Environmental weeds – a field guide for SE Australia*, CRC Weed Management Systems. CH Jerram & Associates, Australia.
 Centre for Agriculture and Bioscience International (CABI), 2022, *Invasive species compendium*, viewed 18 August 2022, from <https://www.cabi.org/isc/datasheet/113484>.
 Drewitz, J.J. & DiTomaso, J.M., 2004, 'Seed biology of jubatagrass (*Cortaderia jubata*)', *Weed Science* 52, 525-530. <https://doi.org/10.1614/WS-03-081R>.
 European and Mediterranean Plant Protection Organization (EPPO), 2018, 'Pest risk analysis for *Cortaderia jubata* EPPO, Paris. <https://pra.eppo.int/prae/19fd73e-0d29-4a86-917f-420d5b803121>
 Global Invasive Species Database. 2022. Species profile: *Cortaderia jubata*. Downloaded from <http://www.iucngisd.org/gisd/species.php?sc=375> on 12-09-2022.
 Lambrinos, J.G., 2000, 'The impact of the invasive alien grass *Cortaderia jubata* (Lemoine) Stapf on an endangered Mediterranean-type shrubland in California', *Diversity and Distributions* 6(5), 217-231. <https://doi.org/10.1046/j.1472-4642.2000.00086.x>.
 Pacific Island Ecosystem Risk (PIER), 2017, '*Cortaderia jubata*', viewed 03 July 2024, from http://www.hear.org/pier/wra/pacific/cortaderia_jubata_htmlwra.htm.

CON2 Socio-economic impact	
CON2a: Safety	
Response: Minor (MN)	Confidence: High
Rationale: <i>Cortaderia jubata</i> has abrasive leaves with sharp and cutting edges that can cause skin cuts (CABI 2023; Henderson 2020).	
References: Centre for Agriculture and Bioscience International (CABI), 2023, <i>Invasive species compendium</i> , viewed 24 August 2023, from https://www.cabi.org/isc/datasheet/113484 . Henderson, L., 2020, <i>Invasive Species Plants in South Africa</i> , Plant Protection Research Institute Handbook 21, Agricultural Research Council, Department of Forestry, Fisheries and the Environment, South Africa.	
CON2b: Material and immaterial assets	
Response: Minor (MN)	Confidence: High
Rationale: The seeds of <i>C. jubata</i> can stick to fruits such as kiwifruit and degrade fruit quality (GISD 2022). In South Africa, <i>C. jubata</i> invades rivers and riparian systems and form thick stands in the streams, preventing free movement and access to water resources for humans and animals (Henderson 2020; Mbele et al. 2023).	
References: Global Invasive Species Database. 2022. Species profile: <i>Cortaderia jubata</i> . Downloaded from http://www.iucngisd.org/gisd/species.php?sc=375 on 12-09-2022. Henderson, L., 2020, <i>Invasive Species Plants in South Africa</i> , Plant Protection Research Institute Handbook 21, Agricultural Research Council, Department of Forestry, Fisheries and the Environment, South Africa. Mbele, T.J., Steenhuisen S., Canavan K., 2023, 'The invasive status of <i>Cortaderia</i> species in South Africa', Poster presentation presented on 06 July 2023 at the National Symposium on Biological Invasions 2023, https://doi.org/10.13140/RG.2.2.36267.41764 .	
CON2c: Health	
Response: Minor (MN)	Confidence: Low
Rationale: In South Africa, fluffy inflorescences of <i>C. jubata</i> are reported to cause respiratory problems, especially for people suffering with asthma (CABI 2022).	
References: Centre for Agriculture and Bioscience International (CABI), 2023, <i>Invasive species compendium</i> , viewed 24 August 2023, from https://www.cabi.org/isc/datasheet/113484 .	
CON2d: Social, spiritual and cultural relations	
Response: Minor (MN)	Confidence: Low
Rationale: Increased density of <i>C. jubata</i> reduces the recreational value of invaded lands and damages grazing lands (CABI 2022; DiTomaso et al. 2010).	
References: Centre for Agriculture and Bioscience International (CABI), 2022, <i>Invasive species compendium</i> , viewed 22 August 2022, from https://www.cabi.org/isc/datasheet/113484 .	

<p>DiTomaso, J.M., Healy, E., Bell, C.E., Drewitz, J. & Stanton, A., 2010, Pampasgrass and jubatagrass threaten California coastal habitats. <i>WEED Research & Information Center</i>. University of California.</p> <p>Lambrinos, J.G., 2000, 'The impact of the invasive alien grass <i>Cortaderia jubata</i> (Lemoine) Stapf on an endangered Mediterranean-type shrubland in California', <i>Diversity and Distributions</i> 6(5), 217-231. https://doi.org/10.1046/j.1472-4642.2000.00086.x.</p>	
CON2 Maximum socio-economic impact	
Response: Minor (MN)	Confidence: High
<p>Rationale: Once <i>C. jubata</i> establishes, recreational value of invaded areas is reduced, and grazing lands are damaged (CABI 2022; DiTomaso et al. 2010). The leaves of <i>C. jubata</i> have sharp, cutting edges that can cause skin cuts while inflorescences cause respiratory problems (CABI 2023; Henderson 2020). Dense stands of <i>C. jubata</i> reduce the recreational value of invaded lands (CABI 2022; DiTomaso et al. 2010).</p>	
<p>References:</p> <p>Centre for Agriculture and Bioscience International (CABI), 2022, <i>Invasive species compendium</i>, viewed 22 August 2022, from https://www.cabi.org/isc/datasheet/113484.</p> <p>DiTomaso, J.M., Healy, E., Bell, C.E., Drewitz, J. & Stanton, A., 2010, Pampasgrass and jubatagrass threaten California coastal habitats. <i>WEED Research & Information Center</i>. University of California.</p> <p>Henderson, L., 2020, <i>Invasive Species Plants in South Africa</i>, Plant Protection Research Institute Handbook 21, Agricultural Research Council, Department of Forestry, Fisheries and the Environment, South Africa.</p> <p>Lambrinos, J.G., 2000, 'The impact of the invasive alien grass <i>Cortaderia jubata</i> (Lemoine) Stapf on an endangered Mediterranean-type shrubland in California', <i>Diversity and Distributions</i> 6(5), 217-231. https://doi.org/10.1046/j.1472-4642.2000.00086.x.</p>	

CON3 Closely related species' environmental impact	
Response: Not scored as CON1 scored	Confidence:
<p>Rationale: There is information to score CON1, so CON3 does not need to be scored as per the framework.</p>	
References:	

CON4 Closely related species' socio-economic impact	
Response: Not scored as CON2 scored	Confidence:
<p>Rationale: There is information to score CON2, so CON4 does not need to be scored as per the framework.</p>	
References:	

CON5 Potential impact	
Response: Major (MR)	Confidence: High
<p>Rationale: <i>Cortaderia jubata</i> has the ability to dominate plant communities, change the functioning of an ecosystem and suppress the growth of surrounding plants (Drewitz & DiTomaso 2004). <i>Cortaderia jubata</i> is an aggressive invader that increases population size and dominates semi-natural areas in a short period of time (CABI 2022). <i>Cortaderia jubata</i> forms dense and impenetrable stands that can damage grazing lands and interfere with afforested areas, can seriously hamper visibility on roadsides and also limit access to certain natural areas including dunes, grasslands, heathlands, forests and inland wetlands (Blood 2001; CABI 2022). <i>Cortaderia jubata</i> transforms the vegetation structure and competes with native plants, and once established, <i>C. jubata</i> reduces the abundance and diversity of native plants (CABI 2022; EPPO 2018; GISD 2022; Lambrinos 200; PIER 2017). The leaves of <i>Cortaderia jubata</i> are highly flammable and can cause intense fires (CABI 2022; Lambrinos 2000). Also, once <i>C. jubata</i> has invaded the area, the recreational value of that area and high conservation sites are reduced (DiTomaso et al. 2010).</p>	
<p>References:</p> <p>Blood, K., 2001, <i>Environmental weeds – a field guide for SE Australia</i>, CRC Weed Management Systems. CH Jerram & Associates, Australia.</p>	

Centre for Agriculture and Bioscience International (CABI), 2022, *Invasive species compendium*, viewed 22 August 2022, from <https://www.cabi.org/isc/datasheet/113484>.

DiTomaso, J.M., Healy, E., Bell, C.E., Drewitz J. & Stanton A., 2010, 'Pampasgrass and jubatagrass threaten California coastal habitats', *WEED Research & Information Center*. University of California.

Drewitz, J.J. & DiTomaso, J.M., 2004, 'Seed biology of jubatagrass (*Cortaderia jubata*)', *Weed Science* 52, 525-530. <https://doi.org/10.1614/WS-03-081R>.

European and Mediterranean Plant Protection Organization (EPPO), 2018, 'Pest risk analysis for *Cortaderia jubata* EPPO, Paris. <https://pra.eppo.int/prae/19fd73e-0d29-4a86-917f-420d5b803121>

Foxcroft, L.C., Richardson, D.M. & Wilson, J.R.U., 2008, 'Ornamental plants as invasive aliens: problems and solution in Kruger National Park, South Africa', *Environmental Management* 41, 32-51. <https://doi.org/10.1007/s00267-007-9027-9>.

Global Invasive Species Database. 2022. Species profile: *Cortaderia jubata*. Downloaded from <http://www.iucngisd.org/gisd/species.php?sc=375> on 12-09-2022.

Lambrinos, J.G., 2000, 'The impact of the invasive alien grass *Cortaderia jubata* (Lemoine) Stapf on an endangered Mediterranean-type shrubland in California', *Diversity and Distributions* 6(5), 217-231. <https://doi.org/10.1046/j.1472-4642.2000.00086.x>.

Pacific Island Ecosystem Risk (PIER), 2017, '*Cortaderia jubata*', viewed 03 July 2024, from http://www.hear.org/pier/wra/pacific/cortaderia_jubata_htmlwra.htm.

4. Management

MAN1 What is the feasibility to stop future immigration?	
Response: Low	Confidence: High
<p>Rationale: Intentional introductions are regulated (Zengeya & Wilson 2020), however, illegal imports will be more difficult to prevent since the inflorescences of <i>C. jubata</i> continue to be grown and traded for home décor and weddings (Sutton et al. 2021), which might drive the informal trade of online seeds. Also, <i>C. jubata</i> is present in countries neighbouring South Africa (i.e., Lesotho and Eswatini) (Mgidi et al. 2007). Due to prolific seed production, and capability of seeds being dispersed by natural mechanisms (i.e., wind and water dispersal), preventing unintentional introductions will be difficult.</p>	
<p>References:</p> <p>Mgidi, T.N., Le Maitre, D.C., Schonegevel, L., Nel, J.L., Rouget, M., & Richardson, D.M., 2007, 'Alien plant invasions-incorporating emerging invaders in regional prioritization: a pragmatic approach for Southern Africa', <i>Journal for Environmental Management</i> 84, 173-187. https://doi.org/10.1016/j.jenvman.2006.05.018.</p> <p>Parsons, W. T. & Cuthbertson, E. G., 2001, <i>Noxious weeds of Australia</i>, Inkata Press, Australia, 698 pp.</p> <p>Sutton, G., Brownes, A., Visser, V., Mapaura, A. & Canavan K., 2021, 'Progress and prospects for the biological control of invasive alien grasses (Poaceae) in South Africa', <i>African Entomology</i> 29(3), 837-858, https://doi.org/10.4001/003.029.0837.</p> <p>Zengeya, T.A. & Wilson, J.R., 2020, <i>The status of biological invasions and their management in South Africa in 2019</i>, South African National Biodiversity Institute, Kirstenbosch and DSI-NRF Centre of Excellence for Invasion Biology, Stellenbosch. http://dx.doi.org/10.5281/zenodo.3947613.</p>	

MAN2 Benefits of the Taxon	
MAN2a Socio-economic benefits of the Taxon	
Response: Low	Confidence: High
<p>Rationale: <i>Cortaderia jubata</i> is cultivated as an ornamental plant, used in the stabilisation of mine-dumps and for erosion control (DiTomaso 2000; Henderson 2020). <i>Cortaderia jubata</i> is also popular in home decorations and for special events (such as weddings – House & Garden 2019; SA Weddings 2020). There are no native species that are similar in appearance to <i>C. jubata</i>, but the use of this plant in floral arrangements is not essential. Therefore, benefits are regarded as low (Fish et al. 2015; Gibbs Russell et al. 1990).</p>	
<p>References:</p> <p>DiTomaso, J., 2000, 'Cortaderia selloana', In: Bossard, C.C., & Randall, J.M. (eds), <i>Invasive plants in California wildlands</i>, University of California Press, USA, 128-133.</p> <p>Fish, L., Mashau, A.C., Moeaha, M.J. & Nembudani, M.T., 2015, 'Identification guide to southern African grasses', <i>Strelitzia</i> 36, 271-276. South African National Biodiversity Institute, Pretoria.</p> <p>Gibbs Russell, G.E., Watson, L., Koekemoer, M., Smook, L., Barker, N.P., Anderson, H.M., et al., 1990, 'Grasses of southern Africa', <i>Memoirs of the Botanical Survey of South Africa No. 58</i>, National Botanical Gardens, Botanical Research Institute, South Africa.</p> <p>Henderson, L., 2020, <i>Invasive Species Plants in South Africa</i>, Plant Protection Research Institute Handbook 21, Agricultural Research Council, Department of Forestry, Fisheries and the Environment, South Africa.</p> <p>House & Garden, 2019, 'Trend alert: pampas grass', viewed 17 August 2023, from https://www.houseandgarden.co.za/design/trend-alert-pampass-grass-31056090.</p> <p>SA Weddings, 2018, '10 must-see floral weddings trends for 2018', viewed 17 August 2023, from https://www.saweddings.co.za/articles/inspiration-51/articles-interviews-55/10-must-see-floral-wedding-trends-for2018.</p>	
MAN2b Environmental benefits of the Taxon	
Response: Low	Confidence: High
<p>Rationale: <i>Cortaderia jubata</i> is used to control soil erosion and stabilise mine-dumps (DiTomaso 2000; Henderson 2020) as a result of the dense fibrous roots growth from shallow short lateral rhizomes (Weed Report 2022). This benefit is regarded as low because <i>C. jubata</i> can be replaced by</p>	

native alternative plants (Fish et al. 2015). Also, prohibition of import into and movement within the country and banned trade of *C. jubata* has limited the use for these benefits.

References:

DiTomaso, J., 2000, '*Cortaderia selloana*', In: Bossard, C.C., & Randall, J.M. (eds), *Invasive plants in California wildlands*, University of California Press, USA, 128-133.

Fish, L., Mashau, A.C., Moeaha, M.J. & Nembudani, M.T., 2015, 'Identification guide to southern African grasses', *Strelitzia* 36, 271-276. South African National Biodiversity Institute, Pretoria.

Henderson, L., 2020, *Invasive Species Plants in South Africa*, Plant Protection Research Institute Handbook 21, Agricultural Research Council, Department of Forestry, Fisheries and the Environment, South Africa.

Weed Report, 2022, 'Pampasgrass and jubatagrass', *Weed Control in Natural Areas in the Western United States*. Available through the Western Society of Weed Science. Assessed on 20 March 2022.

MAN3 Ease of management

MAN3a How accessible are populations?

Response: 1 (moderately accessible)

Confidence: High

Rationale: *Cortaderia jubata* is widely distributed and has no specific habitat preference (Dellow & McCaffery 2009), occurring along roadsides, which may be more accessible, but also occurs in high-altitude grasslands, rocky areas, coastal dune and sandy habitats which may be difficult to access (CABI 2022). Also, because *C. jubata* is used as an ornamental plant, access to individuals found in private gardens (Henderson 2020), will depend on landowners' permission. For these reasons, the response has been scored as moderately accessible.

References:

Centre for Agriculture and Bioscience International (CABI), 2022, *Invasive species compendium*, viewed 22 August 2022, from <https://www.cabi.org/isc/datasheet/113484>.

Dellow, J. & McCaffery, A., 2009, 'Pampas grass', *Primefact*, 697, 1-4.

Henderson, L., 2020, *Invasive Species Plants in South Africa*, Plant Protection Research Institute Handbook 21, Agricultural Research Council, Department of Forestry, Fisheries and the Environment, South Africa.

MAN3b Is detectability critically time-dependent?

Response: 0 (No)

Confidence: Medium

Rationale: Detection of *C. jubata* is not critically time-dependent because flowering occurs year-round, but peaks from mid to late summer (Domenech & Vila 2008). *Cortaderia jubata* has stiff pinkish or purplish flower plumes when young fading to creamy white or dark brown as it matures (GISD 2022; NSW WeedWise 2021). Therefore, *C. jubata* can be easily distinguished from other species, including *C. selloana* which produces silvery-white plumes.

References:

Domenech, R. & Vila, M., 2008, 'Response of the invader *Cortaderia selloana* and two coexisting natives to competition and water stress', *Biological Invasions* 10, 903-912. <https://doi.org/10.1007/s10530-008-9243-0>.

Global Invasive Species Database. 2022. Species profile: *Cortaderia jubata*. Downloaded from <http://www.iucngisd.org/gisd/species.php?sc=375> on 12-09-2022.

NSW WeedWise, 2021, 'Common pampas grass (*Cortaderia jubata*)', viewed 09 November 2021, from <https://weeds.dpi.nsw.gov.au/Weeds/Details/100>.

MAN3c Time to reproduction

Response: 1 (1-3 years)

Confidence: High

Rationale: *Cortaderia jubata* can flower in their first year of growth but is more likely to flower at two to three years old (Parsons & Cuthbertson 2001).

References:

Parsons, W. T. & Cuthbertson, E. G., 2001, *Noxious weeds of Australia*, Inkata Press, Australia, 698 pp.

MAN3d Propagule persistence

Response: 0 (< 1 year)

Confidence: High

Rationale: The plants of *C. jubata* are always female and apomictic (i.e., they reproduce without the need for fertilisation) (Lambrinos 2000). Field experiments of *C. jubata* demonstrated that seeds do

not persist under natural conditions for more than 6 months and there is no persistent seedbank (Drewitz & DiTomaso 2004). This is a notable difference from *C. selloana* whose seeds can persist for up to two years (Blood 2001). It is unclear how long *C. jubata* rhizomes and tillers can persist, it is assumed here that they do not survive long, though in *C. selloana* they persist for more than five years (Parsons & Cuthbertson 2001).

References:

- Blood, K., 2001, *Environmental weeds – a field guide for SE Australia*, CRC Weed Management Systems. CH Jerram & Associates, Australia.
- Drewitz, J. J., & DiTomaso, J. M. 2004, 'Seed biology of jubatagrass (*Cortaderia jubata*)', *Weed science*, 52(4), 525-530.
- Lambrinos, J.G., 2000, 'The impact of the invasive alien grass *Cortaderia jubata* (Lemoine) Stapf on an endangered Mediterranean-type shrubland in California. *Diversity and Distributions* 6(5), pp.217-231. <https://doi.org/10.1046/j.1472-4642.2000.00086.x>.
- Parsons, W. T. & Cuthbertson, E. G., 2001, *Noxious weeds of Australia*, Inkata Press, Australia, 698 pp.

MAN3 Ease of management

Response: Easy

Confidence: High

Rationale: Populations of *C. jubata* that occur in open habitats, such as roadsides, are easily accessible (Dellow & McCaffery 2009), however, management can be complicated by occurrence of populations in inaccessible areas and on private property (CABI 2022; Henderson 2020). Furthermore, *C. jubata* produces high quantities of wind and water-dispersed seeds (Dellow & McCaffery 2009), complicating management efforts by the ability to spread over large distances. Early reproduction and the ability of plants to reproduce without fertilisation can also complicate management (Parsons & Cuthbertson 2001; Drewitz & DiTomaso 2004).

References:

- Blood, K., 2001, *Environmental weeds – a field guide for SE Australia*, CRC Weed Management Systems. CH Jerram & Associates, Australia.
- Centre for Agriculture and Bioscience International (CABI), 2022, *Invasive species compendium*, viewed 22 August 2022, from <https://www.cabi.org/isc/datasheet/113484>.
- Dellow, J. & McCaffery, A., 2009, 'Pampas grass', *Primefact* 697: 1-4.
- Drewitz, J. J., & DiTomaso, J. M. 2004, 'Seed biology of jubata grass (*Cortaderia jubata*)', *Weed science*, 52(4), 525-530.
- Henderson, L., 2020, *Invasive Species Plants in South Africa*, Plant Protection Research Institute Handbook 21, Agricultural Research Council, Department of Forestry, Fisheries and the Environment, South Africa.
- Parsons, W. T. & Cuthbertson, E. G., 2001, *Noxious weeds of Australia*, Inkata Press, Australia, 698 pp.

MAN4 Has the feasibility of eradication been evaluated?

Response: No

Confidence: High

Rationale: There is no evidence to suggest there has been a formal evaluation of *C. jubata* eradication feasibility in South Africa. However, given its current widespread distribution (Henderson 2020), it can be inferred that eradication of *C. jubata* is no longer feasible.

References:

- Henderson, L., 2020, *Invasive Species Plants in South Africa*, Plant Protection Research Institute Handbook 21, Agricultural Research Council, Department of Forestry, Fisheries and the Environment, South Africa.

MAN5 Control options and monitoring approaches available for the Taxon

Response: Control methods applied against *C. jubata* include:

Mechanical control: *Cortaderia jubata* can be physically removed by uprooting plants with protective gloves but this method can be labour intensive (CABI 2022; DiTomaso 2000; GISD 2022; NSW WeedWise 2022). Mechanical control operations should be conducted after rains when the soil is moist to ensure removal of the crown and root systems (CABI 2022; DiTomaso 2000; NSW WeedWise 2022). Bulldozers can also be used (in non-sensitive areas) to uproot dense infestations of *C. jubata*; plants are left to die on site to avoid any spread to areas that have not been invaded (DiTomaso 2000). This type of mechanical control should be done before flowering occurs and old

panicles should be immediately place into disposal bags to avoid seed dispersal (CABI 2022; DiTomaso 2000; NSW WeedWise 2022).

Grazing: Livestock can be used to graze on juvenile *C. jubata* plants to prevent flowers from developing and setting seeds (NSW WeedWise 2022). Grazing can only be done where the risk of new infestation is low and was proven to be successful in New Zealand (DiTomaso 2000).

Chemical control: A number of chemical treatments are also effective and may be more practical for severe infestations of *C. jubata* (GISD 2022). Herbicides are used in areas where infestations are less dense and emerging in order to prevent possible chemical contamination when treating dense infestations (NSW WeedWise 2022). Fire is used to prepare *C. jubata* for spraying by burning plants and allowing recovery before plants are sprayed with herbicide (NSW WeedWise 2022). In South Africa, two glyphosate sodium salts are registered herbicides for *C. jubata*, and they are selected to avoid water pollution (D. Muir, pers. comms., 2024).

Biological control: With the current widespread distribution of *C. jubata*, biological control is a potential management option. A biological control program has been initiated in New Zealand and found two potential biological control agents, a floral-smut fungus, *Ustilago quitensis* Lagerh. (Ustilaginales), and a planthopper, *Sacchasydne subandina* Remes Lenicov and Rossi (Hemiptera: Delphacidae), both of which are still under evaluation (Sutton et al. 2021). Reports from New Zealand have shown that black smut fungus *Ustilago* spp. damages the flower heads of *C. jubata* (Houston & Goeke 2017). Developments in these programmes could help inform biological control efforts in South Africa in the future.

References:

- Centre for Agriculture and Bioscience International (CABI), 2022, Invasive species compendium, viewed 22 August 2022, from <https://www.cabi.org/isc/datasheet/113484>.
- DiTomaso, J., 2002, '*Cortaderia selloana*', In: Bossard, C.C., & Randall, J.M. (eds), *Invasive plants in California wildlands*, University of California Press, USA, 128-133.
- Henderson, L., 2020, *Invasive Species Plants in South Africa*, Plant Protection Research Institute Handbook 21, Agricultural Research Council, Department of Forestry, Fisheries and the Environment, South Africa.
- Houliston, G.J. & Goeke, D.F., 2017, '*Cortaderia* species in New Zealand: patterns of genetic variation in two widespread invasive species', *New Zealand Journal of Ecology* 41(1), 107-112. <https://doi.org/10.20417/nzjecol.41.13>.
- Global Invasive Species Database. 2022. Species profile: *Cortaderia jubata*. Downloaded from <http://www.iucngisd.org/gisd/species.php?sc=375> on 12-09-2022.
- NSW WeedWise, 2022, '*Common pampas grass (Cortaderia jubata)*', viewed 22 August 2022, from <https://weeds.dpi.nsw.gov.au/Weeds/Details/100>.
- Sutton, G., Brownes, A., Visser, V., Mapaura, A. & Canavan K., 2021, 'Progress and prospects for the biological control of invasive alien grasses (Poaceae) in South Africa', *African Entomology* 29(3), 837-858, <https://doi.org/10.4001/003.029.0837>.

MAN6 Any other management considerations to highlight?

Response	No
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5. Calculations

Likelihood = Fairly probable

Parameter	Likelihood	Stages	Final assessment
LIK1	1	P(entry) = 1	P (invasion) = 0.5
LIK2	1		
LIK3	1	P(establishment) = 1	
LIK4	0.5		
LIK5	0.5	P (spread) = 0.5	
LIK6	0.5		

Consequence = Major

Parameter	Mechanism/sector	Response
CON1a	Competition	MR
CON1b	Predation	DD
CON1c	Hybridisation	DD
CON1d	Disease transmission	DD
CON1e	Parasitism	DD
CON1f	Poisoning/toxicity	DD
CON1g	Bio-fouling or other direct physical disturbance	DD
CON1h	Grazing/herbivory/browsing	DD
CON1i	Chemical, physical, structural impact	MR
CON1k	Indirect impacts through interactions with other species	MC
CON1	Maximum environmental impact	MR
CON2a	Safety	MN
CON2b	Material and immaterial assets	MN
CON2c	Health	MN
CON2d	Social, spiritual and cultural relations	MN
CON2	Maximum socio-economic impact	MN
CON3	Environmental impact of closely related taxa	Not scored as CON1 scored
CON4	Socio-economic impact of closely related taxa	Not scored as CON2 scored
CON5	Potential impact based on traits, experiments, or models	MR

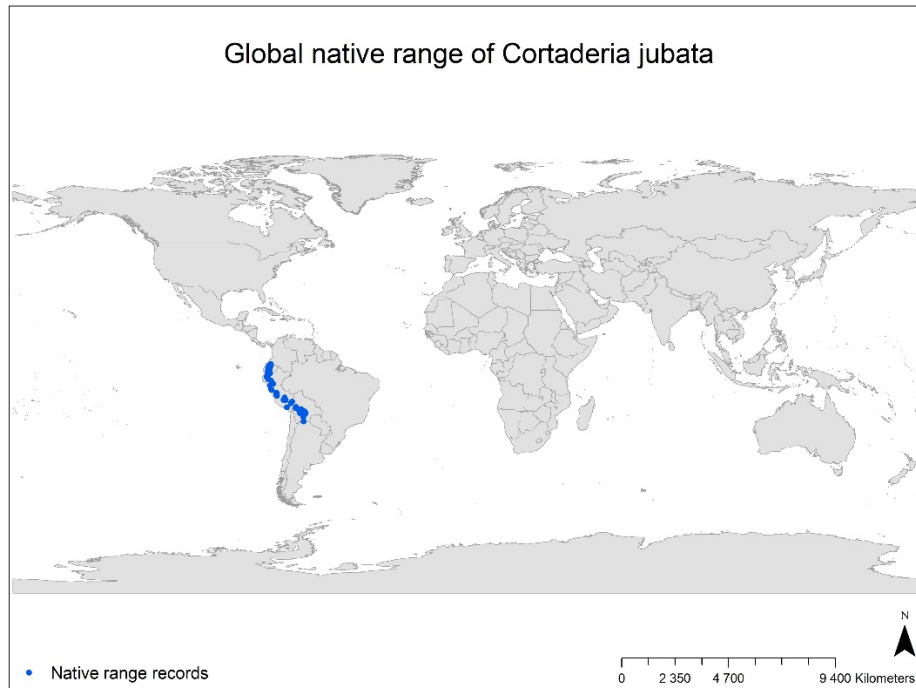
Risk score = High

		Consequences				
		MC	MN	MO	MR	MV
Likelihood	Extremely unlikely	low	low	low	medium	medium
	Very unlikely	low	low	low	medium	high
	Unlikely	low	low	medium	high	high
	Fairly probable	medium	medium	high	high	high
	Probable	medium	high	high	high	high

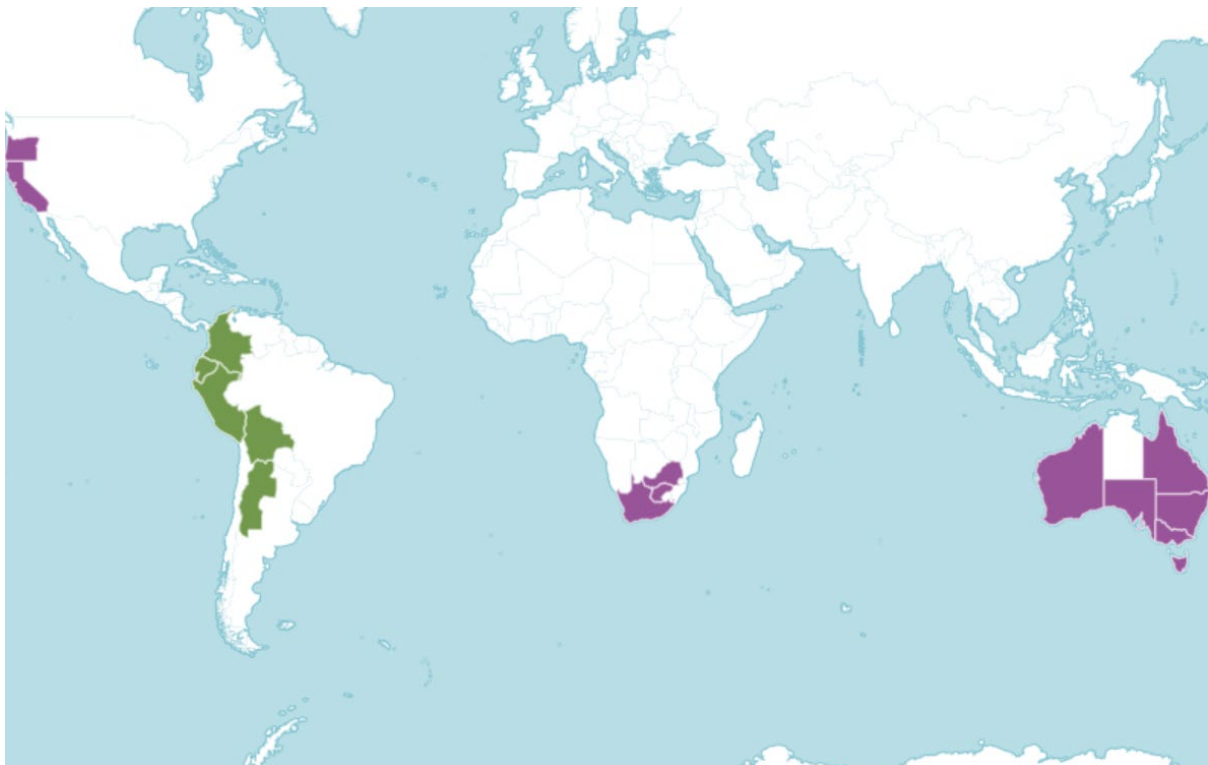
Ease of management = Medium

Parameter	Question	Response
MAN3a	How accessible are populations?	1
MAN3b	Is detectability critically time-dependent?	0
MAN3c	Time to reproduction	1
MAN3d	Propagule persistence	0
MAN3	SUM	2

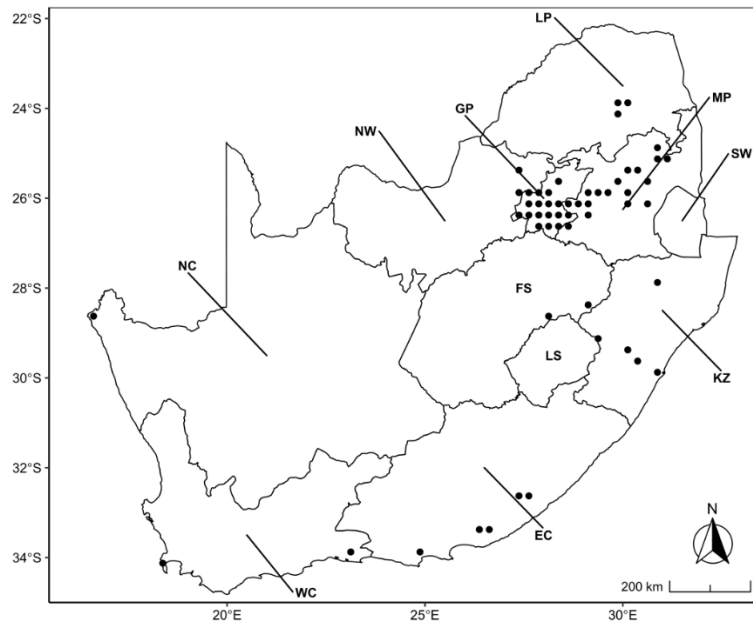
Appendix BAC7: The global native range of *Cortaderia jubata* (Lemoine ex Carriere) Stapf. Locality records sourced from GBIF.org (16 August 2022) GBIF Occurrence Download <https://doi.org/10.15468/dl.4pcrbv>.



Appendix BAC8 (a): The global alien range of *Cortaderia jubata* (Lemoine ex Carriere) Stapf. indicated in purple (native range indicated in green). Source: POWO, 2024, '*Cortaderia jubata* (Lemoine) Stapf', viewed 03 December 2024, from: <https://powo.science.kew.org/taxon/urn:lsid:ipni.org:names:66302-2>




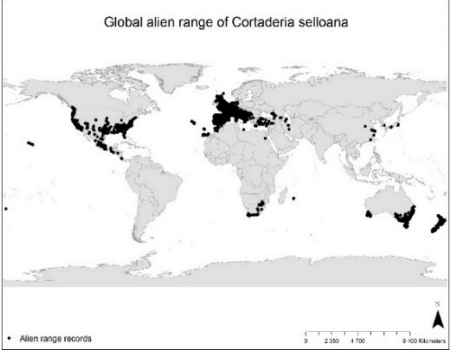
Appendix BAC8 (b): The South African distribution of *Cortaderia jubata* (Lemoine) Stapf. taken from Sutton et al. (2021).



Reference:

Sutton, G., Brownes, A., Visser, V., Mapaura, A. & Canavan K., 2021, 'Progress and prospects for the biological control of invasive alien grasses (Poaceae) in South Africa', *African Entomology* 29(3), 837-858, <https://doi.org/10.4001/003.029.0837>.

Risk Analysis Report: *Cortaderia selloana*

<p>Taxon: <i>Cortaderia selloana</i> (Schult.) Asch. & Graebn.</p>	<p>Area: South Africa</p>
<p>Compiled by: Thembelihle Mbele</p>	<p>Approved by:</p>
<p>Picture of Taxon</p>  <p>Photo: by T.M. Mokotjomela (Home garden in Jacobsdal, Free State, 25 October 2021).</p>	<p>Alien distribution map</p>  <p>Reference: GBIF.org (22 March 2022) GBIF Occurrence Download https://doi.org/10.15468/dl.g8bauq</p>
<p>Risk Assessment summary: <i>Cortaderia selloana</i> was introduced to South Africa in 1958 as an ornamental plant, and for mine-dump stabilisation purposes, and now occurs in seven provinces. <i>Cortaderia selloana</i> can reduce native plant species richness, life form richness, and species cover (scored as Major impacts). <i>Cortaderia selloana</i> has sharp leaves that cause superficial cuts to humans and animals and flowers that provoke allergies in summer (scored as Minor impacts). Trade of <i>C. selloana</i> is banned in South Africa yet the species, in particular the inflorescences, are still widely sold through informal trades for decoration and as ornamentals.</p>	<p>Risk score: High</p>
<p>Management options summary: Management of <i>C. selloana</i> is complicated since it can occur in inaccessible areas such as high-altitude grassland, rocky areas, coastal dunes and sandy habitats. Early reproduction, propagule persistence (e.g., seeds can survive for up to two years), and spread via wind and water dispersed seeds, rhizomes and tillers, complicate management. The benefits of <i>C. selloana</i> as an ornamental, for soil erosion control and stabilising mine dumps are regarded as low as they can be replaced by native taxa and other means of controlling soil erosion and mine dumps. In the 2014 and 2016 NEM:BA A&IS Lists, sterile cultivars or hybrids were not listed (with two cultivars exempt), this provision was removed in the 2020 lists. No evidence was found that any cultivars are sterile or that sterility on its own would be sufficient to reduce the threat of invasions. Available control methods for <i>C. selloana</i> include grazing, mechanical, and chemical control, and potentially biological control.</p>	<p>Ease of management: Medium</p>
<p>Recommendations: Due to the widespread distribution of <i>C. selloana</i> and negative impacts on biodiversity, the recommendations are: 1) to retain <i>C. selloana</i> as category 1b; 2) that all populations in riparian areas should be targeted for removal; 3) the feasibility of biological control should be explored; and 4) no exemptions should be provided for sterile cultivars or hybrids.</p>	<p>Listing under NEM:BA A&IS lists of 2020: 1b Recommended listing category: 1b</p>

Suggested citation: SANBI (unpublished) Risk analysis of *Cortaderia selloana* (Schult.) Asch. & Graebn. for South Africa as per the risk analysis for alien taxa framework v1.2, approved by the South African Alien Species Risk Analysis Review Panel on 03 December 2024, pp 19, <http://dx.doi.org/10.5281/zenodo.14265013>

1. Background

BAC1 Name of assessor(s)	
Name of lead assessor	Thembelihle Mbele
Additional assessor (1)	
Additional assessor (2)	
BAC2 Contact details of assessor (s)	
Lead assessor	Organisational affiliation: South African National Biodiversity Institute
	email: T.Mbele@sanbi.org.za
	Phone: +2763 446 7124
Additional assessor (1)	Organisational affiliation:
	email:
	Phone:
Additional assessor (2)	Organisational affiliation:
	email:
	Phone:
BAC3 Name(s) and contact details of expert(s) consulted	
Expert (1)	Name: Dr Thabiso Mokotjomela
	email: t.mokotjomela@sanbi.org.za
	Phone: +2773 324 6118
Expert (2)	Name:
	email:
	Phone:
Comments: Dr Thabiso Mokotjomela assisted with biology and ecology concepts relating to the invasion of <i>Cortaderia selloana</i> ; provided corrections on the report; interpretation of scores and extra sources of information on the processes and mechanism of biological invasions.	
BAC4 Scientific name of Taxon under assessment	
Taxon name: <i>Cortaderia selloana</i>	Authority: (Schult.) Asch. & Graebn.
Comments: <i>Cortaderia selloana</i> has a verified and accepted taxonomic status (ITIS 2021; SANBI 2016).	
References: Integrated Taxonomic Information System (ITIS), 2021, viewed 03 November 2021, from https://www.itis.gov/servlet/SingleRpt/SingleRpt#null . South African National Biodiversity Institute (SANBI), 2016, 'Botanical Database of Southern Africa (BODATSA) [dataset]', viewed 22 October 2024, from https://posa.sanbi.org/sanbi/Explore	
BAC5 Synonym(s) considered	
Synonyms: <i>Cortaderia dioica</i> Speg. <i>Arundo dioeca</i> Spreng. <i>Arundo selloana</i> Schult. & Schult. f. <i>Cortaderia argentea</i> (Nees) Stapf. <i>Arundo kila</i> Spreng. ex Steud. <i>Gynerium argenteum</i> Nees <i>Gynerium dioicum</i> (Spreng.) Dallere <i>Gynerium purpureum</i> Carrere <i>Moorea argentea</i> (Nees) Lem <i>Gynerium argenteum</i> var. <i>argenteum</i> Nees.	
Comments: There are ten synonyms of <i>C. selloana</i> listed by ITIS (2021). This assessment considered all these synonyms in its literature search. However, no additional information was obtained through searching for the synonyms.	
References: Integrated Taxonomic Information System (ITIS), 2021, viewed 03 November 2021, from https://www.itis.gov/servlet/SingleRpt/SingleRpt?search_topic=TSN&search_value=41597#null .	
BAC6 Common name(s) considered	
Common names: pampas grass silver pampas grass Uruguayan pampas grass.	

Comments: There are three English common names of <i>C. selloana</i> (ITIS 2021). Silver pampas grass is the most widely used common name for <i>C. selloana</i> (CABI 2021).	
References: Centre for Agriculture and Bioscience International (CABI), 2021, <i>Invasive species compendium</i> , viewed 03 November 2021, from https://www.cabi.org/isc/datasheet/11872#totaxonomicTree . Integrated Taxonomic Information System (ITIS), 2021, viewed 03 November 2021 Available from URL. https://www.itis.gov/servlet/SingleRpt/SingleRpt?search_topic=TSN&search_value=41597#null .	
BAC7 What is the native range of the Taxon?	
Response: South America	Confidence: High
Comments: <i>Cortaderia selloana</i> is native to Argentina, Chile, Brazil and Uruguay (CABI 2021; Zuloaga et al. 2008). See map in Appendix BAC7.	
References: Centre for Agriculture and Bioscience International (CABI), 2021, <i>Invasive species compendium</i> , viewed 03 November 2021, from https://www.cabi.org/isc/datasheet/11872#totaxonomicTree . Zuloaga, F.O., Morrone, O. & Belgrano, M.J., 2008, <i>Monographs in Systematic Botany</i> , Missouri Botanical Garden Press, USA, pp.3348.	
BAC8 What is the global alien range of the Taxon?	
Response: Europe North America Africa Oceania Australia	Confidence: High
Comments: <i>Cortaderia selloana</i> is present in 65 countries across five continents but is considered the most problematic in South Africa, New Zealand and the United States (CABI 2022; Houlston & Goeke 2017; Robinson 1984) and is mainly found at low altitudes (CABI 2021; DAISIE 2009). See map in Appendix BAC 8a.	
References: Centre for Agriculture and Bioscience International (CABI), 2021, <i>Invasive species compendium</i> , viewed 03 November 2021, from https://www.cabi.org/isc/datasheet/11872#totaxonomicTree . Delivering Alien Invasive Species Inventories for Europe (DAISIE), 2009, <i>Cortaderia selloana</i> , from http://www.europe-aliens.org/index.jsp . Houlston, G.J. & Goeke, D.F., 2017, 'Cortaderia species in New Zealand: patterns of genetic variation in two widespread invasive species', <i>New Zealand Journal of Ecology</i> 41(1), 107-112. https://doi.org/10.20417/nzjecol.41.13 . Robinson, E.R., 1984, 'Naturalized species of <i>Cortaderia</i> (Poaceae) in Southern Africa', <i>South African Journal of Botany</i> 3, 343-346. https://doi.org/10.1016/S0022-4618(16)30023-7 .	
BAC9 Geographic scope = the Area under consideration	
Area of assessment: South Africa.	
Comments: The geographic scope of this assessment is limited to South Africa.	
BAC10 Is the Taxon present in the Area?	
Response: Yes	Confidence: Medium
Comments: <i>Cortaderia selloana</i> was introduced to South Africa in 1958 as an ornamental plant, and for mine-dump stabilisation purposes (Henderson 2020) and has been reported across almost all provinces in South Africa except the Northern Cape and North West but is most problematic in the Western Cape, Eastern Cape and Gauteng (Henderson 2020). See map in Appendix BAC8b. However, plants identified as <i>C. selloana</i> in New Zealand (invaded range) are not genetically the same taxon as plants identified as <i>C. selloana</i> in its native range (Houlston & Goeke, 2017). Therefore, the identification of <i>C. selloana</i> in South Africa might also need reassessing, and so the confidence is scored as Medium.	

References: Henderson, L., 2020, <i>Invasive Species Plants in South Africa</i> , Plant Protection Research Institute Handbook 21, Agricultural Research Council, Department of Forestry, Fisheries and the Environment, South Africa. Houlston, G. J. & Goeke, D. F., 2017, 'Cortaderia spp. in New Zealand: patterns of genetic variation in two widespread invasive species', <i>New Zealand Journal of Ecology</i> 41, 107-112. https://doi.org/10.20417/nzjecol.41.13 .		
BAC11 Availability of physical specimen		
Response: Yes		Confidence in ID: High
Herbarium or museum accession number: Physical specimens can be found at the Pretoria National Herbarium – PRE, accession number – 897056 (collected and identified by T. Jaca and S. Miza on the 4 th of March 2014)		
Herbarium – NH, accession number – 0148490 (collected and identified by M.D. Cheek on the 11 th of May 2013).		
References: South African National Biodiversity Institute (SANBI), 2016, 'Botanical Database of Southern Africa (BODATSA) [dataset]', viewed 22 October 2024, from https://posa.sanbi.org/sanbi/Explore		
BAC12 Is the Taxon native to the Area or part of the Area?		
The Taxon is native to (part of) the Area.	No	Confidence: High
The Taxon is alien in (part of) the Area.	Yes	Confidence: High
Comments: <i>Cortaderia selloana</i> is native to South America (CABI 2021; Zuloaga et al. 2008).		
References: Centre for Agriculture and Bioscience International (CABI), 2021, <i>Invasive species compendium</i> , viewed 03 November 2021, from https://www.cabi.org/isc/datasheet/11872#totaxonomicTree . Zuloaga, F.O., Morrone, O. & Belgrano, M.J., 2008, <i>Monographs in Systematic Botany</i> , Missouri Botanical Garden Press, USA, pp.3348.		
BAC13 What is the Taxon's introduction status in the Area?		
The Taxon is in cultivation/containment.	Yes	Confidence: High
The Taxon is present outside of cultivation/containment.	Yes	Confidence: High
The Taxon has established/naturalised.	Yes	Confidence: High
The Taxon is invasive.	Yes	Confidence: High
Comments: <i>Cortaderia selloana</i> has been planted as an ornamental and in landscapes for aesthetic purposes, also as stabilisation for mine-dumps and erosion control (Henderson 2020). <i>Cortaderia selloana</i> has naturalised and is invasive in South Africa (CABI 2021; Robinson 1984).		
References: Centre for Agriculture and Bioscience International (CABI), 2021, <i>Invasive species compendium</i> , viewed 03 November 2021, from https://www.cabi.org/isc/datasheet/11872#totaxonomicTree . Henderson, L., 2020, <i>Invasive Species Plants in South Africa</i> , Plant Protection Research Institute Handbook 21, Agricultural Research Council, Department of Forestry, Fisheries and the Environment, South Africa. Robinson, E.R., 1984, 'Naturalized species of <i>Cortaderia</i> (Poaceae) in Southern Africa', <i>South African Journal of Botany</i> , 3, 343-346. https://doi.org/10.1016/S0022-4618(16)30023-7 .		
BAC14 Primary (introduction) pathways		
Release	erosion control	Confidence: High
Escape	horticulture	Confidence: High
	ornamental purpose other than horticulture	Confidence: High
Contaminant	none	Confidence: Low
Stowaway	machinery/ equipment	Confidence: Low
Corridor	Interconnected waterways	Confidence: Medium
Unaided	natural dispersal across borders of invasive alien organisms	Confidence: High

Comments: *Cortaderia selloana* was introduced to South Africa as an ornamental plant, for mine-dump stabilisation, and for erosion control (e.g., as a barrier or windbreak) (CABI 2021; DAISIE 2009; DiTomaso 2000; Henderson 2020). *Cortaderia selloana* is present in two neighbouring countries (i.e., Eswatini and Lesotho) (CABI 2021; Mgidi et al 2007). Future introductions of *C. selloana* may occur through natural dispersal because seeds are very light and normally wind-dispersed but can also be spread by water, machinery, and garden waste (CABI 2021; Dellow & McCaffery 2009).

References:

- Centre for Agriculture and Bioscience International (CABI), 2021, Invasive species compendium, viewed 03 November 2021, from <https://www.cabi.org/isc/datasheet/11872#totaxonomicTree>.
- Delivering Alien Invasive Species Inventories for Europe (DAISIE), 2009, *Cortaderia selloana*, from <http://www.europe-aliens.org/index.jsp>.
- Dellow, J. & McCaffery, A., 2009, 'Pampas grass', *Primefact* 697, 1-4.
- DiTomaso, J., 2000, '*Cortaderia selloana*', In: Bossard, C.C., & Randall, J.M. (eds), *Invasive plants in California wildlands*, University of California Press, USA, 128-133.
- Henderson, L., 2020, *Invasive Species Plants in South Africa*, Plant Protection Research Institute Handbook 21, Agricultural Research Council, Department of Forestry, Fisheries and the Environment, South Africa.
- Mgidi, T.N., Le Maitre, D.C., Schonegevel, L., Nel, J.L., Rouget, M., & Richardson, D.M., 2007, 'Alien Plant Invasions-incorporating emerging invaders in regional prioritization: a pragmatic approach for Southern Africa', *Journal for Environmental Management* 84, 173-187. <https://doi.org/10.1016/j.jenvman.2006.05.018>.

2. Likelihood

LIK1 Likelihood of entry via unaided primary pathways	
Response: Present in the country (p = 1)	Confidence: Medium
<p>Rationale: <i>Cortaderia selloana</i> is present in the country. In terms of the likelihood of future introductions, <i>C. selloana</i> is present in two countries neighbouring South Africa (i.e., Eswatini and Lesotho) (CABI 2021; Mgidi et al. 2007). Moreover, <i>C. selloana</i> abundantly produces small wind dispersed seeds which are also well-suited to dispersal by water (DAISIE 2009; Parsons & Cuthbertson 2001). Therefore, it is probable that <i>C. selloana</i> would re-enter South Africa through unaided pathways (e.g., re-entry via wind dispersal across the border and through interconnected waterways).</p>	
<p>References: Centre for Agriculture and Bioscience International (CABI), 2021, Invasive species compendium, viewed 03 November 2021, from https://www.cabi.org/isc/datasheet/11872#totaxonomicTree. Delivering Alien Invasive Species Inventories for Europe (DAISIE), 2009, <i>Cortaderia selloana</i>, from http://www.europe-aliens.org/index.jsp. Mgidi, T.N., Le Maitre, D.C., Schonegevel, L., Nel, J.L., Rouget, M., & Richardson, D.M., 2007, 'Alien Plant Invasions-incorporating emerging invaders in regional prioritization: a pragmatic approach for Southern Africa', <i>Journal for Environmental Management</i> 84, 173-187. https://doi.org/10.1016/j.jenvman.2006.05.018. Parsons, W.T. & Cuthbertson, E.G., 2001, <i>Noxious weeds of Australia</i>, Inkata Press, Australia, 698 pp.</p>	
LIK2 Likelihood of entry via human aided primary pathways	
Response: Present in the country (p = 1)	Confidence: Medium
<p>Rationale: <i>Cortaderia selloana</i> is present in the country. In terms of the likelihood of future introductions, <i>C. selloana</i> is cultivated as an ornamental plant in South Africa (Henderson 2020). Therefore, <i>C. selloana</i> could be intentionally brought into South Africa as an ornamental plant, particularly from neighbouring countries (e.g., Lesotho) where <i>C. selloana</i> is present. Also, with the continuing popularity of <i>C. selloana</i> inflorescences for home décor and weddings (SA Weddings 2020; House and Garden 2020), new varieties may be imported illegally as seeds are sold through online platforms such as Amazon. Entry via human-aided pathways is therefore probable (p = 1).</p>	
<p>References: Centre for Agriculture and Bioscience International (CABI), 2021, Invasive species compendium, viewed 03 November 2021, from https://www.cabi.org/isc/datasheet/11872#totaxonomicTree. Henderson, L., 2020, <i>Invasive Species Plants in South Africa</i>, Plant Protection Research Institute Handbook 21, Agricultural Research Council, Department of Forestry, Fisheries and the Environment, South Africa. House and Garden. 2019. Trend alert: pampas grass. https://www.houseandgarden.co.za/design/trend-alert-pampass-grass-31056090 (accessed 21 March 2023). SA Weddings. 2018. 10 must-see floral weddings trends for 2018. Available at: https://www.saweddings.co.za/articles/inspiration-51/articles-interviews-55/10-must-see-floral-wedding-trends-for2018 (accessed 21 March 2023). van Wilgen, B.W., & Wilson, J.R., 2018, <i>The status of biological invasions and their management in South Africa in 2017</i>, South African National Biodiversity Institute, Kirstenbosch and DST-NRF Centre of Excellence for Invasion Biology, Stellenbosch.</p>	
LIK3 Habitat suitability	
Response: Probable (p = 1)	Confidence: High
<p>Rationale: <i>Cortaderia selloana</i> is found in a wide range of ecosystems (Dellow & McCaffery 2009). <i>Cortaderia selloana</i> often occurs in high-altitude grasslands, rocky areas and in coastal dune and sandy habitats as wind breaks together with trees (CABI 2021). Moreover, <i>C. selloana</i> mostly invades disturbed sites, such as recently cleared vegetation or plantations, waste deposits, swamps and wetlands (CABI 2021; DAISIE 2009; Parsons & Cuthbertson 2001). However, while <i>C. selloana</i> typically invades disturbed habitats, recently, it has been found in pristine grasslands in the Drakensburg Mountains, KwaZulu-Natal Province (Sutton et al. 2021). The habitat conditions required for the growth and survival of <i>C. selloana</i> are met in a large part of South Africa (Henderson</p>	

2020; Mucina & Rutherford 2006). Therefore, the habitat suitability of *C. selloana* in South Africa is probable (p = 1).

References:

Centre for Agriculture and Bioscience International (CABI), 2021, Invasive species compendium, viewed 03 November 2021, from <https://www.cabi.org/isc/datasheet/11872#totaxonomicTree>.

Delivering Alien Invasive Species Inventories for Europe (DAISIE), 2009, *Cortaderia selloana*, from <http://www.europe-aliens.org/index.jsp>.

Dellow, J. & McCaffery, A., 2009, 'Pampas grass', *Primefact* 697, 1-4.

Henderson, L., 2020, *Invasive Species Plants in South Africa*, Plant Protection Research Institute Handbook 21, Agricultural Research Council, Department of Forestry, Fisheries and the Environment, South Africa.

Mucina, L. & Rutherford, M.C., 2006, *The vegetation of South Africa, Lesotho and Swaziland, Strelitzia 19*, South African National Biodiversity Institute, Pretoria.

Parsons, W. T. & Cuthbertson, E. G., 2001, *Noxious weeds of Australia*, Inkata Press, Australia, 698 pp.

Sutton G., Brownes A., Visser V., Mapaura A., & Canavan K., 2021, 'Progress and prospects for the biological control of invasive alien grasses (Poaceae) in South Africa, *African Entomology*, 29(3), 837-858, <https://doi.org/10.4001/003.029.0837>

LIK4 Climate suitability

Response: Probable (p = 1)

Confidence: Low

Rationale: *Cortaderia selloana* occurs in areas with mean annual precipitation of 430-860 mm and temperatures of 8-18°C (CABI 2021). In southern California, *C. selloana* has escaped urban landscapes (Okada et al. 2007) and has invaded coastal sage scrub drainages and riparian areas (Bossard et al. 2000; Lambrinos 2001, 2002). These areas are typically moist to wet (which has been observed in South Africa as well), suggesting that *C. selloana* requires adequate moisture to become established; however, once established *C. selloana* can tolerate moderate drought, winter frost, intense sunlight and warm summer temperatures (Bossard et al. 2000; Lambrinos 2002). *Cortaderia selloana* is widely distributed across much of the southern and eastern parts of South Africa, where it invades both disturbed habitats and native grasslands (Robinson 1984). *Cortaderia selloana* has a large potentially climatically suitable range in South Africa, Lesotho and Eswatini (Mgidi et al. 2007). Therefore, climatic suitability for *C. selloana* is scored as probable (p = 1).

References:

Bossard, C.C., Randall, J.M. & Houshovsky, M.C., 2000, *Invasive plants in California wildlands*, University of California, USA.

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LIK5 Unaided secondary (dispersal) pathways

Response: Probable (p = 1)

Confidence: High

Rationale: *Cortaderia selloana* produces considerable quantities of wind-dispersed seeds (up to 100 000 per flower head) (DAISIE 2009; Dellow & McMaffery 2009). *Cortaderia selloana* seeds are light

and normally wind-dispersed but can be dispersed by water (CABI 2021; DAISIE 2009; Parsons & Cuthbertson 2001). Seeds can disperse up to 25 km from the mother plant (CABI 2021; Dellow & McCaffery 2009). Local wind direction determines the spatial distribution of seedlings (CABI 2021; Saura-Mas & Lloret 2005). Also, *C. selloana* reproduces asexually, and can spread through rhizomes and tillers (Parsons & Cuthbertson 2001). Importantly, sterile cultivars can also become invasive through rhizomes and tillers, even though dispersal distances would be less (Henderson & Wilson 2017). Therefore, it is probable ($p = 1$) that *C. selloana* could spread unaided to other parts of South Africa and fairly probable ($p = 0.5$) even for plants with sterile seeds to spread asexually.

References:

- Centre for Agriculture and Bioscience International (CABI), 2021, Invasive species compendium, viewed 03 November 2021, from <https://www.cabi.org/isc/datasheet/11872#totaxonomicTree>.
- Delivering Alien Invasive Species Inventories for Europe (DAISIE), 2009, *Cortaderia selloana*, from <http://www.europe-aliens.org/index.jsp>.
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LIK6 Human aided secondary (dispersal) pathways

Response: Probable ($p = 1$)

Confidence: High

Rationale: *Cortaderia selloana* may be dispersed by people for aesthetic purposes as an ornamental, and for erosion control or stabilisation in mine-dumps (CABI 2021; DiTomaso 2000; Henderson 2020). Also, due to high adaptability, disposed *C. selloana* at dumping sites can facilitate the establishment of new populations (CABI 2021; DAISIE 2009; Parsons & Cuthbertson 2001). The popularity of *C. selloana* inflorescences home décor and weddings continues to grow (SA Weddings 2020; House and Garden 2020) and this could aid future introductions.

References:

- Centre for Agriculture and Bioscience International (CABI), 2021, Invasive species compendium, viewed 03 November 2021, from <https://www.cabi.org/isc/datasheet/11872#totaxonomicTree>.
- Delivering Alien Invasive Species Inventories for Europe (DAISIE), 2009, *Cortaderia selloana*, from <http://www.europe-aliens.org/index.jsp>.
- DiTomaso, J., 2000, '*Cortaderia selloana*', In: Bossard, C.C., & Randall, J.M. (eds), *Invasive plants in California wildlands*, University of California Press, USA, 128-133.
- Henderson, L., 2020, *Invasive Species Plants in South Africa*, Plant Protection Research Institute Handbook 21, Agricultural Research Council, Department of Forestry, Fisheries and the Environment, South Africa.
- House and Garden. 2019. Trend alert: pampas grass. <https://www.houseandgarden.co.za/design/trend-alert-pampas-grass-31056090> (accessed 21 March 2023).
- Parsons, W.T. & Cuthbertson, E.G., 2001, *Noxious weeds of Australia*, Inkata Press, Australia, 698 pp.
- SA Weddings. 2018. 10 must-see floral weddings trends for 2018. Available at: <https://www.saweddings.co.za/articles/inspiration-51/articles-interviews-55/10-must-see-floral-wedding-trends-for2018> (accessed 21 March 2023).

3. Consequences

CON1 Environmental impact	
CON1a: Competition	
Response: Major (MR)	Confidence: Medium
Rationale: <i>Cortaderia selloana</i> can colonise semi-natural and natural areas and dominate in a short period of time (CABI 2021; Dellow & McMaffery 2009; Domenech et al. 2006). Once established, <i>C. selloana</i> tends to exclude most other species and forms impenetrable clumps (CABI 2021; DAISIE 2009; Dellow & McMaffery 2009; Domenech et al. 2006). Prolific seed production, rapid growth and accumulation of above and below-ground biomass allows <i>C. selloana</i> to acquire light, moisture, and nutrients to the detriment of native plant species (CABI 2021). Invasion of <i>C. selloana</i> can reduce plant species diversity, life form richness, native species cover, and limit secondary succession from abandoned agricultural or pastoral lands (CABI 2021; Domenech et al. 2006). Notably, these studies were not conducted in South Africa.	
References: Centre for Agriculture and Bioscience International (CABI), 2021, Invasive species compendium, viewed 03 November 2021, from https://www.cabi.org/isc/datasheet/11872#totaxonomicTree . Delivering Alien Invasive Species Inventories for Europe (DAISIE), 2009, <i>Cortaderia selloana</i> , from http://www.europe-aliens.org/index.jsp . Dellow, J. & McCaffery, A., 2009, 'Pampas grass', <i>Primefact</i> 697, 1-4. Domenech, R., Vila, M., Gesti, J. & Serrasoles, I., 2006, 'Neighbourhood association of <i>Cortaderia selloana</i> invasion, soil properties and plant community structure in Mediterranean coastal grasslands', <i>Acta Oecologica</i> , 29, 171-177. https://doi.org/10.1016/j.actao.2005.09.004 .	
CON1b: Predation	
Response: Data Deficient (DD)	Confidence: High
Rationale: <i>Cortaderia selloana</i> is a plant that is not predatory.	
References:	
CON1c: Hybridisation	
Response: Data Deficient (DD)	Confidence: Low
Rationale: There is no native <i>Cortaderia</i> species in South Africa, therefore, <i>Cortaderia selloana</i> does not hybridise with any native species. There are no data on whether the two <i>Cortaderia</i> species present in South Africa are hybridising.	
References:	
CON1d: Transmission of disease	
Response: Data Deficient (DD)	Confidence: Low
Rationale: There is no documented literature on <i>C. selloana</i> transmitting diseases.	
References:	
CON1e: Parasitism	
Response: Data Deficient (DD)	Confidence: High
Rationale: <i>Cortaderia selloana</i> is not a parasitic plant.	
References:	
CON1f: Poisoning/toxicity	
Response: Data Deficient (DD)	Confidence: Low
Rationale: <i>Cortaderia selloana</i> is not poisonous as animals can feed on young plants (NSW WeedWise 2021). When old, the leaf blades of <i>C. selloana</i> are unpalatable due to their sharp edges (Cal-IPC 2018).	
References: California Invasive Plant Council (Cal-IPC), 2018, 'California Invasive Plant Inventory', Cal-IPC Publication 2006-2018. Berkeley, CA. from https://www.cal-ipc/plants/inventory/ . Accessed on 8 November 2021. NSW WeedWise, 2021, 'Common pampas grass (<i>Cortaderia selloana</i>)', viewed 09 November 2021, from https://weeds.dpi.nsw.gov.au/Weeds/Details/100 .	
CON1g: Bio-fouling or other direct physical disturbance	
Response: Data Deficient (DD)	Confidence: Low
Rationale:	
References:	
CON1h: Grazing/herbivory/browsing	

Response: Data Deficient (DD)	Confidence: High
Rationale: <i>Cortaderia selloana</i> is a plant and does not graze nor browse.	
References:	
CON1i: Chemical, physical or structural impact on ecosystem	
Response: Major (MR)	Confidence: High
Rationale: <i>Cortaderia selloana</i> can alter the structure of invaded communities (Blood 2001). <i>Cortaderia selloana</i> can exclude ground flora and seriously impede over-storey regeneration (Muyt 2001). Decomposition of leaf litter in <i>C. selloana</i> is low and therefore reduces the total soil nitrogen while increasing the carbon-nitrogen ratio (Domenech et al. 2006). <i>Cortaderia selloana</i> increases the frequency and intensity of veld fires through the build-up of dry leaves when senescing (CABI 2021; Domenech et al. 2006). Flowering stalks of <i>C. selloana</i> produce large amounts of flammable material and increase fire intensity and fire hazards (Bossard et al. 2000; DiTomaso 2000).	
References:	
Blood, K., 2001, <i>Environmental weeds – a field guide for SE Australia</i> , CRC Weed Management Systems. CH Jerram & Associates, Australia.	
Bossard, C.C., Randall, J.M. & Houshovsky, M.C., 2000, <i>Invasive plants in California wildlands</i> , University of California, USA.	
Centre for Agriculture and Bioscience International (CABI), 2021, Invasive species compendium, viewed 03 November 2021, from https://www.cabi.org/isc/datasheet/11872#totaxonomicTree .	
DiTomaso, J., 2000, ' <i>Cortaderia selloana</i> ', In: Bossard, C.C., & Randall, J.M. (eds), <i>Invasive plants in California wildlands</i> , University of California Press, USA, 128-133.	
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Muyt, A., 2001, <i>Bush invaders of south-east Australia. A guide to the identification and control of environmental weeds found in south-east Australia</i> , R.G. & F.J. Richardson, Australia.	
CON1k: Indirect impacts through interactions with other species	
Response: Minimal Concern (MC)	Confidence: Medium
Rationale: <i>Cortaderia selloana</i> leaves are extremely sharp and are highly undesirable as food or shelter to wildlife and can cause physical harm to those animals (Cal-IPC 2018).	
References:	
California Invasive Plant Council (Cal-IPC), 2018, 'California Invasive Plant Inventory', Cal-IPC Publication 2006-2018. Berkeley, CA. from https://www.cal-ipc/plants/inventory/ . Accessed on 8 November 2021.	
CON1 Maximum environmental impact	
Response: Major (MR)	Confidence: Medium
Rationale: <i>Cortaderia selloana</i> colonises natural and semi-natural habitats (CABI 2021; Dellow & McCaffery 2009; Domenech et al. 2006; Sutton et al. 2021) displacing native plants and reducing habitat suitability for native species (CABI 2021; Henderson 2020). Once established, <i>C. selloana</i> is very competitive, restricting the establishment of native trees, and can become a fire hazard due to high biomass and highly flammable leaves (Dellow & McCaffery 2009). The leaf blades of <i>C. selloana</i> are undesirable as food or shelter for wildlife and can cause physical harm to animals (Cal-IPC 2018).	
References:	
Centre for Agriculture and Bioscience International (CABI), 2021, Invasive species compendium, viewed 03 November 2021, from https://www.cabi.org/isc/datasheet/11872#totaxonomicTree .	
California Invasive Plant Council (Cal-IPC), 2018, 'California Invasive Plant Inventory', Cal-IPC Publication 2006-2018. Berkeley, CA. from https://www.cal-ipc/plants/inventory/ . Accessed date: 08 November 2021.	
Delivering Alien Invasive Species Inventories for Europe (DAISIE), 2009, <i>Cortaderia selloana</i> , from http://www.europe-aliens.org/index.jsp .	
Dellow, J. & McCaffery, A., 2009, 'Pampas grass', <i>Primefact</i> 697, 1-4.	
Domenech, R., Vila, M., Gesti, J. & Serrasoies, I., 2006, 'Neighbourhood association of <i>Cortaderia selloana</i> invasion, soil properties and plant community structure in Mediterranean coastal grasslands', <i>Acta Oecologica</i> , 29, 171-177. https://doi.org/10.1016/j.actao.2005.09.004 .	
Sutton G., Brownes A., Visser V., Mapaura A., & Canavan K., 2021, 'Progress and prospects for the biological control of invasive alien grasses (Poaceae) in South Africa', <i>African Entomology</i> , 29(3), 837-858. https://doi.org/10.4001/003.029.0837 .	

CON2 Socio-economic impact	
CON2a: Safety	
Response: Minor (MN)	Confidence: Medium
Rationale: <i>Cortaderia selloana</i> has sharp leaves that can cause superficial cuts to humans and animals. Dense stands can affect visibility along road margins (Cal-IPC 2018; Domenech et al. 2006).	
References: California Invasive Plant Council (Cal-IPC), 2018, 'California Invasive Plant Inventory', Cal-IPC Publication 2006-2018. Berkeley, CA. from https://www.cal-ipc/plants/inventory/ . Accessed date: 08 November 2021. Domenech, R., Vila, M., Gesti, J. & Serrasoles, I., 2006, 'Neighbourhood association of <i>Cortaderia selloana</i> invasion, soil properties and plant community structure in Mediterranean coastal grasslands', <i>Acta Oecological</i> 29, 171-177. https://doi.org/10.1016/j.actao.2005.09.004 .	
CON2b: Material and immaterial assets	
Response: Minor (MN)	Confidence: Medium
Rationale: <i>Cortaderia selloana</i> forms dense and impenetrable stands that can reduce grazing, interfere with afforested areas, and inland wetlands (Blood 2001; CABI 2021; Domenech et al. 2006).	
References: Blood, K., 2001, <i>Environmental weeds – a field guide for SE Australia</i> , CRC Weed Management Systems. CH Jerram & Associates, Australia. Centre for Agriculture and Bioscience International (CABI), 2021, Invasive species compendium, viewed 03 November 2021, from https://www.cabi.org/isc/datasheet/11872#totaxonomicTree . Domenech, R., Vila, M., Gesti, J. & Serrasoles, I., 2006, 'Neighbourhood association of <i>Cortaderia selloana</i> invasion, soil properties and plant community structure in Mediterranean coastal grasslands', <i>Acta Oecological</i> , 29, 171-177. https://doi.org/10.1016/j.actao.2005.09.004 .	
CON2c: Health	
Response: Minor (MN)	Confidence: Medium
Rationale: <i>Cortaderia selloana</i> has sharp leaves that can cause skin-deep cuts while the flowers can also cause allergies in summer (CABI 2021).	
References: Centre for Agriculture and Bioscience International (CABI), 2021, Invasive species compendium, viewed 03 November 2021, from https://www.cabi.org/isc/datasheet/11872#totaxonomicTree .	
CON2d: Social, spiritual and cultural relations	
Response: Minor (MN)	Confidence: Medium
Rationale: Increased density of <i>C. selloana</i> reduces the recreational value of invaded areas (CABI 2021).	
References: Centre for Agriculture and Bioscience International (CABI), 2021, Invasive species compendium, viewed 03 November 2021, from https://www.cabi.org/isc/datasheet/11872#totaxonomicTree .	
CON2 Maximum socio-economic impact	
Response: Minor (MN)	Confidence: Medium
Rationale: <i>Cortaderia selloana</i> can reduce grazing capacity and hinder access to certain natural areas by forming dense and impenetrable stands (Blood 2001; CABI 2021; Domenech et al. 2006). <i>Cortaderia selloana</i> has sharp leaves that can cause skin-deep cuts and in summer, the flowers can cause allergies. (Cal-IPC 2018; Domenech et al. 2006). <i>Cortaderia selloana</i> reduces the recreational value of invaded areas (CABI 2021).	
References: Blood, K., 2001, <i>Environmental weeds – a field guide for SE Australia</i> , CRC Weed Management Systems. CH Jerram & Associates, Australia. Centre for Agriculture and Bioscience International (CABI), 2021, Invasive species compendium, viewed 03 November 2021, from https://www.cabi.org/isc/datasheet/11872#totaxonomicTree . California Invasive Plant Council (Cal-IPC), 2018, 'California Invasive Plant Inventory', Cal-IPC Publication 2006-2018. Berkeley, CA. from https://www.cal-ipc/plants/inventory/ . Accessed date Accessed on 8 November 2021.	

Domenech, R., Vila, M., Gesti, J. & Serrasoles, I., 2006, 'Neighbourhood association of *Cortaderia selloana* invasion, soil properties and plant community structure in Mediterranean coastal grasslands', *Acta Oecological* 29, 171-177. <https://doi.org/10.1016/j.actao.2005.09.004>.

CON3 Closely related species' environmental impact

Response: Not scored as CON1 scored	Confidence:
Rationale: There is information to score CON1, so CON3 does not need to be scored as per the framework.	
References:	

CON4 Closely related species' socio-economic impact

Response: Not scored as CON2 scored	Confidence:
Rationale: There is information to score CON2, so CON4 does not need to be scored as per the framework.	
References:	

CON5 Potential impact

Response: Major (MR)	Confidence: Medium
<p>Rationale: <i>Cortaderia selloana</i> has the ability to dominate plant communities, change the functioning of an ecosystem and suppress the growth of surrounding plants (Drewitz & DiTomaso 2004). <i>Cortaderia selloana</i> dominates natural and semi-natural areas in a short period of time (CABI 2021; Dellow & McCaffery 2009; Domenech et al. 2006). <i>Cortaderia selloana</i> transforms the vegetation structure and competes with native plants. Once established, <i>C. selloana</i> reduces the abundance and diversity of native plants (CABI 2021; DAISIE 2009; Dellow & McCaffery 2009; Domenech et al. 2006). Invasion of <i>C. selloana</i> can reduce native plant species cover, life form richness and secondary succession from abandoned agricultural or pasture lands (Domenech et al. 2006). Also, once <i>C. selloana</i> has invaded the area, the recreational value of that area is reduced (Foxcroft et al. 2008).</p>	
<p>References:</p> <p>Centre for Agriculture and Bioscience International (CABI), 2021, Invasive species compendium, viewed 03 November 2021, from https://www.cabi.org/isc/datasheet/11872#totaxonomicTree.</p> <p>Delivering Alien Invasive Species Inventories for Europe (DAISIE), 2009, <i>Cortaderia selloana</i>, from http://www.europe-aliens.org/index.jsp.</p> <p>Dellow, J. & McCaffery, A., 2009, 'Pampas grass', <i>Primefact</i> 697, 1-4.</p> <p>Domenech, R., Vila, M., Gesti, J. & Serrasoles, I., 2006, 'Neighbourhood association of <i>Cortaderia selloana</i> invasion, soil properties and plant community structure in Mediterranean coastal grasslands', <i>Acta Oecological</i> 29, 171-177. https://doi.org/10.1016/j.actao.2005.09.004.</p> <p>Drewitz, J.J. & DiTomaso, J.M., 2004, 'Seed biology of jubatagrass (<i>Cortaderia jubata</i>)', <i>Weed Science</i> 52, 525-530. https://doi.org/10.1614/WS-03-081R.</p> <p>Foxcroft, L.C., Richardson, D.M. & Wilson, J.R.U., 2008, 'Ornamental plants as invasive aliens: problems and solution in Kruger National Park, South Africa', <i>Environmental Management</i> 41, 32-51. https://doi.org/10.1007/s00267-007-9027-9.</p>	

4. Management

MAN1 What is the feasibility to stop future immigration?	
Response: Low	Confidence: Medium
<p>Rationale: Controlling the importation of <i>C. selloana</i> through human-aided pathways of introduction should be feasible, given that South Africa has strict legislation and processes around the import of alien plant material (van Wilgen & Wilson 2018). However, the inflorescences of <i>C. selloana</i> are popular, therefore, are continuing to be grown and traded for home décor and weddings (SA Weddings 2020; House and Garden 2020), which might drive the informal trade of online seeds for the desire of new varieties. Also, <i>C. selloana</i> is present in neighbouring countries to South Africa (i.e., Lesotho and Eswatini) (Mgidi et al. 2007), and is known for prolific seed production, which can be wind and water dispersed (DAISIE 2009; Parsons & Cuthbertson 2001). Therefore, it is probable that in future, <i>C. selloana</i> will enter the country through informal trade and unaided pathways (i.e., wind and water dispersal).</p>	
<p>References: Delivering Alien Invasive Species Inventories for Europe (DAISIE), 2009, <i>Cortaderia selloana</i>, from http://www.europe-aliens.org/index.jsp. Mgidi, T.N., Le Maitre, D.C., Schonegevel, L., Nel, J.L., Rouget, M., & Richardson, D.M., 2007, 'Alien Plant Invasions-incorporating emerging invaders in regional prioritization: a pragmatic approach for Southern Africa', <i>Journal for Environmental Management</i>, 84, 173-187. https://doi.org/10.1016/j.jenvman.2006.05.018. Parsons, W. T. & Cuthbertson, E. G., 2001, <i>Noxious weeds of Australia</i>, Inkata Press, Australia, 698 pp. van Wilgen, B.W., & Wilson, J.R., 2018, <i>The status of biological invasions and their management in South Africa in 2017</i>, South African National Biodiversity Institute, Kirstenbosch and DST-NRF Centre of Excellence for Invasion Biology, Stellenbosch.</p>	
MAN2 Benefits of the Taxon	
MAN2a Socio-economic benefits of the Taxon	
Response: Low	Confidence: Medium
<p>Rationale: <i>Cortaderia selloana</i> is cultivated and sold as an ornamental plant (Henderson 2020; DiTomaso 2000), although it is no longer sold in nurseries because of the legislation. However, inflorescences are popular for home décor and weddings (SA Weddings 2020; House and Garden 2020) and continue to be sold through the informal trade. This benefit is regarded as low because it can be replaced by native taxa such as <i>Melinis repens</i> (Fish et al. 2015; Gibbs Russell et al. 1990).</p> <p>In the 2014 and 2016 NEM:BA A&IS Lists, sterile cultivars of <i>C. selloana</i> were exempt, with two cultivars exempt on the unofficial consensus list, this provision was removed in the 2020 NEM:BA A&IS Lists (Chetty et al. 2024). No evidence was found that there are sterile cultivars or that sterility on its own is sufficient to reduce the risk of invasion to an acceptable level.</p>	
<p>References: Chetty, D., Datta, A., Kumschick, S., Wilson, J.R.U., Nchu, F. & Geerts, S., 2024, 'Regulatory options for cultivars and hybrids of invasive plant species – the South African experience', <i>Invasive Plant Science and Management</i>, 1-39, https://doi.org/10.1017/inp.2024.24 DiTomaso, J., 2000, 'Cortaderia selloana', In: Bossard, C.C., & Randall, J.M. (eds), <i>Invasive plants in California wildlands</i>, University of California Press, USA, 128-133. Fish, L., Mashau, A.C., Moeaha, M.J. & Nembudani, M.T., 2015, 'Identification guide to southern African grasses', <i>Strelitzia</i>, 36, 271–276. South African National Biodiversity Institute, Pretoria. Gibbs Russell, G.E., Watson, L., Koekemoer, M., Smook, L., Barker, N.P., Anderson, H.M. & Dallwitz, M.J., 1990, 'Grasses of southern Africa', <i>Memoirs of the Botanical Survey of South Africa No. 58</i>, National Botanical Gardens, Botanical Research Institute, South Africa. Henderson, L., 2020, <i>Invasive Species Plants in South Africa</i>, Plant Protection Research Institute Handbook 21, Agricultural Research Council, Department of Forestry, Fisheries and the Environment, South Africa. House and Garden. 2019. Trend alert: pampas grass. https://www.houseandgarden.co.za/design/trend-alert-pampas-grass-31056090 (accessed 21 March 2023).</p>	

SA Weddings. 2018. 10 must-see floral weddings trends for 2018. Available at: https://www.saweddings.co.za/articles/inspiration-51/articles-interviews-55/10-must-see-floral-wedding-trends-for2018 (accessed 21 March 2023).	
MAN2b Environmental benefits of the Taxon	
Response: Low	Confidence: High
Rationale: <i>Cortaderia selloana</i> is used for soil erosion control and mine-dump stabilisation because of dense fibrous roots growth from shallow short lateral rhizomes (Weed Report, 2022; DiTomaso 2000; Henderson 2020). This benefit is regarded as low in South Africa. Also it can be replaced by other taxa such as <i>Andropogon huilense</i> or other means of controlling soil erosion and mine-dump stabilisation such as mulching and terracing (Fish et al. 2015).	
References: DiTomaso, J., 2000, ' <i>Cortaderia selloana</i> ', In: Bossard, C.C., & Randall, J.M. (eds), <i>Invasive plants in California wildlands</i> , University of California Press, USA, 128-133. Fish, L., Mashau, A.C., Moeaha, M.J. & Nembudani, M.T., 2015, 'Identification guide to southern African grasses', <i>Strelitzia</i> 36, 271-276. South African National Biodiversity Institute, Pretoria. Henderson, L., 2020, <i>Invasive Species Plants in South Africa</i> , Plant Protection Research Institute Handbook 21, Agricultural Research Council, Department of Forestry, Fisheries and the Environment, South Africa. Weed Report. 2022. Pampasgrass and jubatagrass. <i>Weed Control in Natural Areas in the Western United States</i> . Available through the Western Society of Weed Science. Assessed on 20 March 2022.	
MAN3 Ease of management	
MAN3a How accessible are populations?	
Response: 1 (Moderately accessible)	Confidence: High
Rationale: <i>Cortaderia selloana</i> is widely distributed across South Africa (Dellow & McCaffery 2009; Sutton et al., 2021). <i>Cortaderia selloana</i> occurs in numerous places such as roadsides, which are easy to access while some occur in areas such as high-altitude grassland, rocky areas, coastal dune and sandy habitats which may be difficult to access (CABI 2021). Accessibility of <i>C. selloana</i> on private properties may pose a challenge for managers.	
References: Centre for Agriculture and Bioscience International (CABI), 2021, Invasive species compendium, viewed 03 November 2021, from https://www.cabi.org/isc/datasheet/11872#totaxonomicTree . Dellow, J. & McCaffery, A., 2009, 'Pampas grass', <i>Primefact</i> 697, 1-4. Sutton G., Brownes A., Visser V., Mapaura A., & Canavan K., 2021, 'Progress and prospects for the biological control of invasive alien grasses (Poaceae) in South Africa', <i>African Entomology</i> 29(3), 837-858. https://doi.org/10.4001/003.029.0837	
MAN3b Is detectability critically time-dependent?	
Response: 0 (No)	Confidence: Medium
Rationale: <i>Cortaderia selloana</i> detectability is not critically time-dependent because flowering occurs year-round, but peaks from mid to late summer (Domenech & Vila 2008). It is also very easy to identify vegetatively. <i>Cortaderia selloana</i> has dense and large seed heads of 25–100 cm that are usually white or silvery in colour when young (NSW WeedWise 2021).	
References: Domenech, R. & Vila, M., 2008, 'Response of the invader <i>Cortaderia selloana</i> and two coexisting natives to competition and water stress', <i>Biological Invasions</i> , 10, 903-912. https://doi.org/10.1007/s10530-008-9243-0 . NSW WeedWise, 2021, 'Common pampas grass (<i>Cortaderia selloana</i>)', viewed 09 November 2021, from https://weeds.dpi.nsw.gov.au/Weeds/Details/100 .	
MAN3c Time to reproduction	
Response: 1 (1-3 years)	Confidence: High
Rationale: <i>Cortaderia selloana</i> can flower in the plant's first season but is more likely to do so after two to three years (Parsons & Cuthbertson 2001).	
References:	

Parsons, W.T. & Cuthbertson, E.G., 2001, *Noxious weeds of Australia*, Inkata Press, Australia, 698 pp.

MAN3d Propagule persistence

Response: 1 (1-5 years)

Confidence: High

Rationale: *Cortaderia selloana* reproduces both sexually (via seeds) and asexually (via rhizome and tillers) (Parsons & Cuthbertson 2001). Seeds remain viable for up to two years (Blood 2001). However, for asexual reproduction, it is possible for the propagules to persist for more than five years. By contrast seeds of *Cortaderia selloana* only persist for six months under natural conditions (Drewitz & DiTomaso 2004).

References:

Blood, K., 2001, *Environmental weeds – a field guide for SE Australia*, CRC Weed Management Systems. CH Jerram & Associates, Australia.

Drewitz, J. J., & DiTomaso, J. M. 2004, 'Seed biology of jubatagrass (*Cortaderia jubata*)', *Weed science*, 52(4), 525-530.

Parsons, W. T. & Cuthbertson, E. G., 2001, *Noxious weeds of Australia*, Inkata Press, Australia, 698 pp.

MAN3 Ease of management

Response: Medium

Confidence: Medium

Rationale: Populations of *C. selloana* occurring in open habitats such as roadsides are easily accessible (Dellow & McCaffery 2009), however, management can be complicated by occurrence of populations in inaccessible areas and on private property (CABI 2021; Henderson 2020). Furthermore, *C. selloana* producing large number of wind and water-dispersed seeds (DAISIE 2009; Dellow & McCaffery 2009) which complicates the management. Early reproduction and propagule persistence of *C. selloana* can also complicate management (Blood 2001; Parsons & Cuthbertson 2001)

References:

Blood, K., 2001, *Environmental weeds – a field guide for SE Australia*, CRC Weed Management Systems. CH Jerram & Associates, Australia.

Centre for Agriculture and Bioscience International (CABI), 2021, Invasive species compendium, viewed 03 November 2021, from <https://www.cabi.org/isc/datasheet/11872#totaxonomicTree>.

Delivering Alien Invasive Species Inventories for Europe (DAISIE), 2009, *Cortaderia selloana*, from <http://www.europe-aliens.org/index.jsp>.

Dellow, J. & McCaffery, A., 2009, 'Pampas grass', *Primefact* 697, 1-4.

Henderson, L., 2020, *Invasive Species Plants in South Africa*, Plant Protection Research Institute Handbook 21, Agricultural Research Council, Department of Forestry, Fisheries and the Environment, South Africa.

Parsons, W.T. & Cuthbertson, E.G., 2001, *Noxious weeds of Australia*, Inkata Press, Australia, 698 pp.

MAN4 Has the feasibility of eradication been evaluated?

Response: No

Confidence: High

Rationale: There is no evidence to suggest there has been a formal evaluation of *C. selloana* eradication feasibility in South Africa. However, given its current widespread distribution (Henderson 2020), it can be inferred that eradication of *C. selloana* is no longer feasible.

References:

Henderson, L., 2020, *Invasive Species Plants in South Africa*, Plant Protection Research Institute Handbook 21, Agricultural Research Council, Department of Forestry, Fisheries and the Environment, South Africa.

MAN5 Control options and monitoring approaches available for the Taxon

Response: Control methods applied against *C. selloana* include:

Mechanical control: *Cortaderia selloana* can be physically removed by uprooting plants with protective gloves (CABI 2021; DiTomaso 2000; NSW WeedWise 2021). This should be done after rains when the soil is moist to ensure removal of the crown and root systems (CABI 2021; DiTomaso 2000; NSW WeedWise 2021). Bulldozers can be used in disturbed areas to uproot dense infestations

of *C. selloana*, plants are left to die on site to avoid any spread to areas which have not been infested (DiTomaso 2000). This should be done before flowering and old panicles should be immediately placed into disposal bags to avoid seed dispersal (CABI 2021; DiTomaso 2000; NSW WeedWise 2021). However, according to Ezemvelo KwaZulu-Natal Wildlife, South Africa, manual removal is difficult because of associated health risks to the teams, and it also appears to promote significant regeneration from the soil seed bank in addition to seeds dropped during clearing, which fuels new invasions. Therefore, repeated control interventions are required at each site to bring *C. selloana* under control.

Grazing: Livestock can be used to graze on juvenile *C. selloana* plants to prevent flowers from developing and setting seeds (NSW WeedWise 2021). This control method proved to be successful in New Zealand but can only be done where the risk of new infestation is low (DiTomaso 2000).

Chemical control: The pre-emergent herbicides metolachlor, oryzalin, and napropamide have been recorded as effective in controlling *C. selloana* (CABI 2021), though as with all herbicides it will be important to check the most recent regulations as to what is permitted. Herbicides are used in areas where invasion is sparse (NSW WeedWise 2021). Prior to foliar spray treatment, *C. selloana* stands are burned (NSW WeedWise 2021).

Biological control: Biological control is a potential management option for *C. selloana*. A biological control program has been initiated in New Zealand and has found two potential biological control agents, a floral-smut fungus, *Ustilago quitensis* Lagerh. (Ustilaginales), and a planthopper, *Sacchasydne subandina* Remes Lenicov and Rossi (Hemiptera: Delphacidae) (Sutton et al. 2021). Both agents are still under evaluation (Sutton et al. 2021). Developments in these programmes could help inform biological control efforts in South Africa in the future.

References:

- Centre for Agriculture and Bioscience International (CABI), 2021, Invasive species compendium, viewed 03 November 2021, from <https://www.cabi.org/isc/datasheet/11872#totaxonomicTree>.
- DiTomaso, J., 2002, '*Cortaderia selloana*', In: Bossard, C.C., & Randall, J.M. (eds), *Invasive plants in California wildlands*, University of California Press, USA, 128-133.
- Henderson, L., 2020, *Invasive Species Plants in South Africa*, Plant Protection Research Institute Handbook 21, Agricultural Research Council, Department of Forestry, Fisheries and the Environment, South Africa.
- NSW WeedWise, 2021, 'Common pampas grass (*Cortaderia selloana*)', viewed 09 November 2021, from <https://weeds.dpi.nsw.gov.au/Weeds/Details/100>.
- Sutton, G., Bownes, A., Visser, V., Canavan, K., 2021, 'Progress and prospects for the biological control of invasive alien grasses (Poaceae) in South Africa', *African Entomology*. 29(3): 837-858. <https://doi.org/10.4001/003.029.0837>.

MAN6 Any other management considerations to highlight?

Response	No
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5. Calculations

Likelihood = Probable

Parameter	Likelihood	Stages	Final assessment
LIK1	1	P(entry) = 1	P (invasion) = 1
LIK2	1		
LIK3	1	P(establishment) = 1	
LIK4	1		
LIK5	1	P (spread) = 1	
LIK6	1		

Consequence = Major

Parameter	Mechanism/sector	Response
CON1a	Competition	MR
CON1b	Predation	DD
CON1c	Hybridisation	DD
CON1d	Disease transmission	DD
CON1e	Parasitism	DD
CON1f	Poisoning/toxicity	DD
CON1g	Bio-fouling or other direct physical disturbance	DD
CON1h	Grazing/herbivory/browsing	DD
CON1i	Chemical, physical, structural impact	MO
CON1k	Indirect impacts through interactions with other species	MC
CON1	Maximum environmental impact	MR
CON2a	Safety	MN
CON2b	Material and immaterial assets	MN
CON2c	Health	MN
CON2d	Social, spiritual and cultural relations	MN
CON2	Maximum socio-economic impact	MN
CON3	Environmental impact of closely related taxa	Not scored as CON1 scored
CON4	Socio-economic impact of closely related taxa	Not scored as CON2 scored
CON5	Potential impact based on traits, experiments, or models	MR

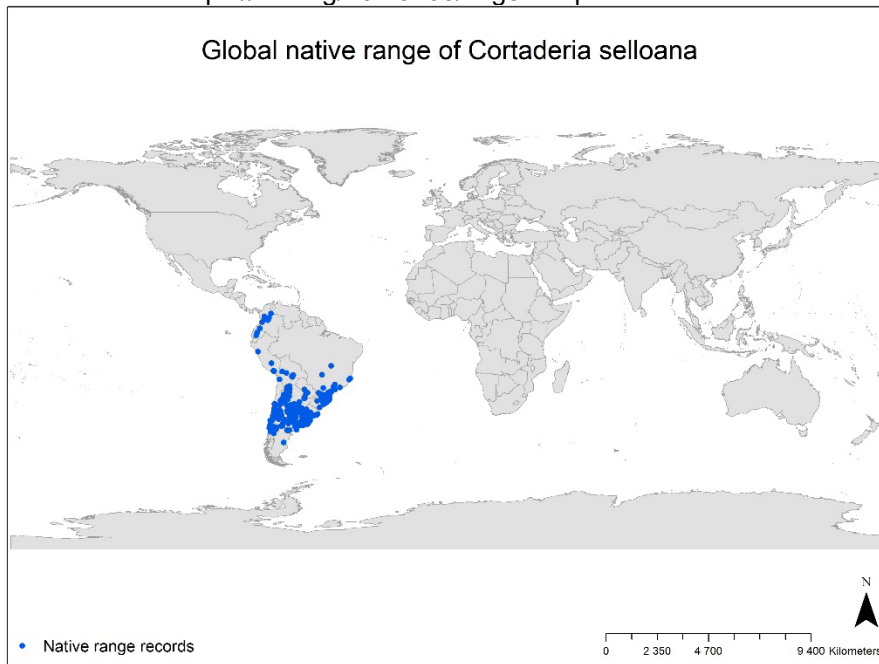
Risk score = High

		Consequences				
		MC	MN	MO	MR	MV
Likelihood	Extremely unlikely	low	low	low	medium	medium
	Very unlikely	low	low	low	medium	high
	Unlikely	low	low	medium	high	high
	Fairly probable	medium	medium	high	high	high
	Probable	medium	high	high	high	high

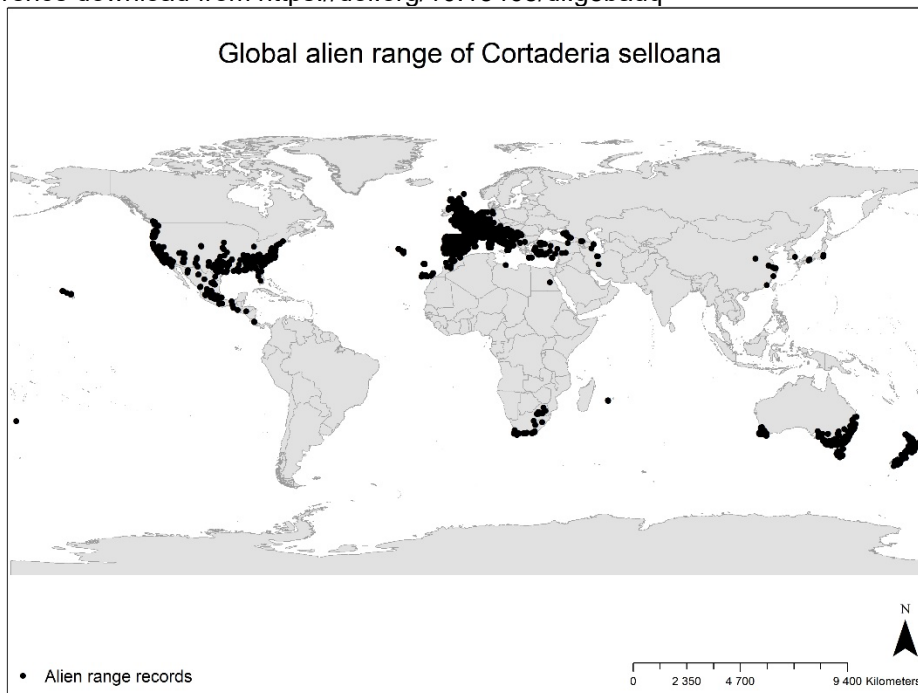
Ease of management = Medium

Parameter	Question	Response
MAN3a	How accessible are populations?	1
MAN3b	Is detectability critically time-dependent?	0
MAN3c	Time to reproduction	1
MAN3d	Propagule persistence	1
MAN3	SUM	3

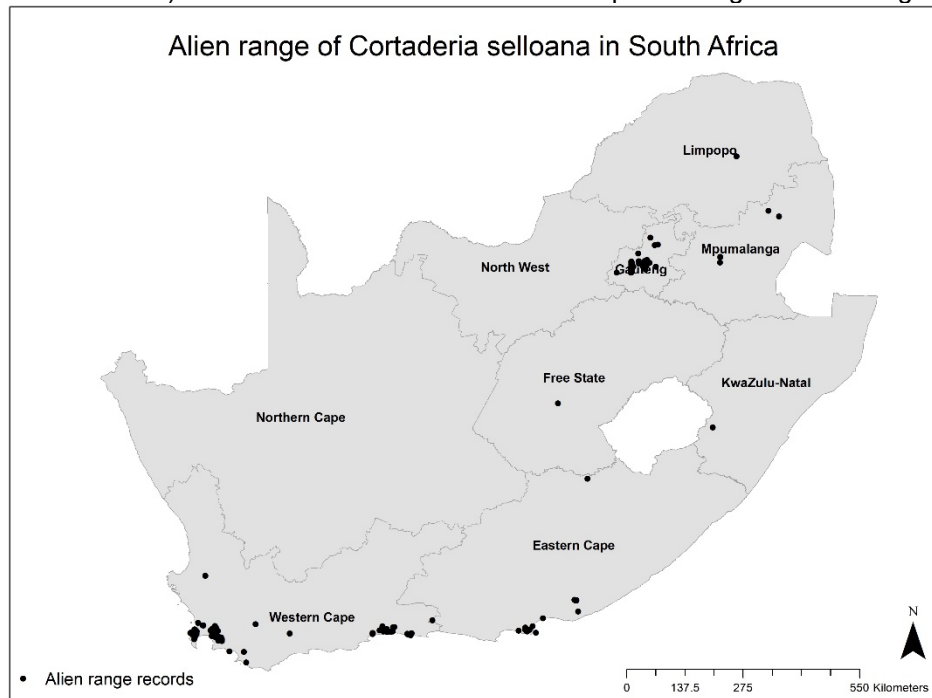
Appendix BAC7: Map of Global Native range of *Cortaderia selloana* GBIF (5 November 2021). GBIF occurrence download from <https://doi.org/10.15468/dl.g8bauq>



Appendix BAC8(a): Map of Global Alien range of *Cortaderia selloana* GBIF (5 November 2021). GBIF occurrence download from <https://doi.org/10.15468/dl.g8bauq>



Appendix BAC8(b): Map of Alien range of *Cortaderia selloana* (Schult.) Asch. & Graebn. in South Africa (5 November 2021). GBIF occurrence download from <https://doi.org/10.15468/dl.g8bauq>.



Supplementary data

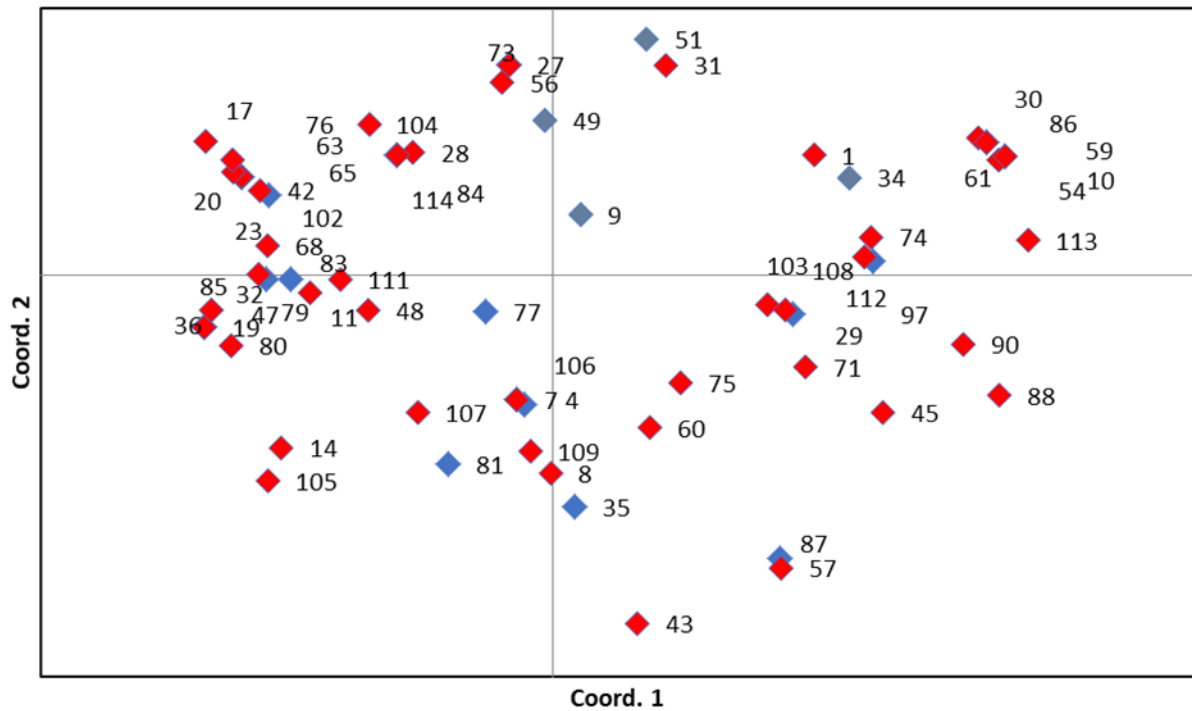


Figure 3.3.1: Principal coordinates analysis (PCoA) built on Euclidean genetic distances between *C. selloana* samples in South Africa using Cor-7, Cor-11, Cor-36, Cor-43, Cor-46, Cor-47, Cor-49 and Cor-56-1 microsatellite primers. Coordinate 1 account for 16.50 % and Coordinate 2 accounts for 15.28 % of the variation. The blue colour refers to lineage one and the red colour refer to lineage two. The two lineages were determined from STRUCTURE and the optimal populations were $k=2$ according to the evanno method (Figure 3.3.5).

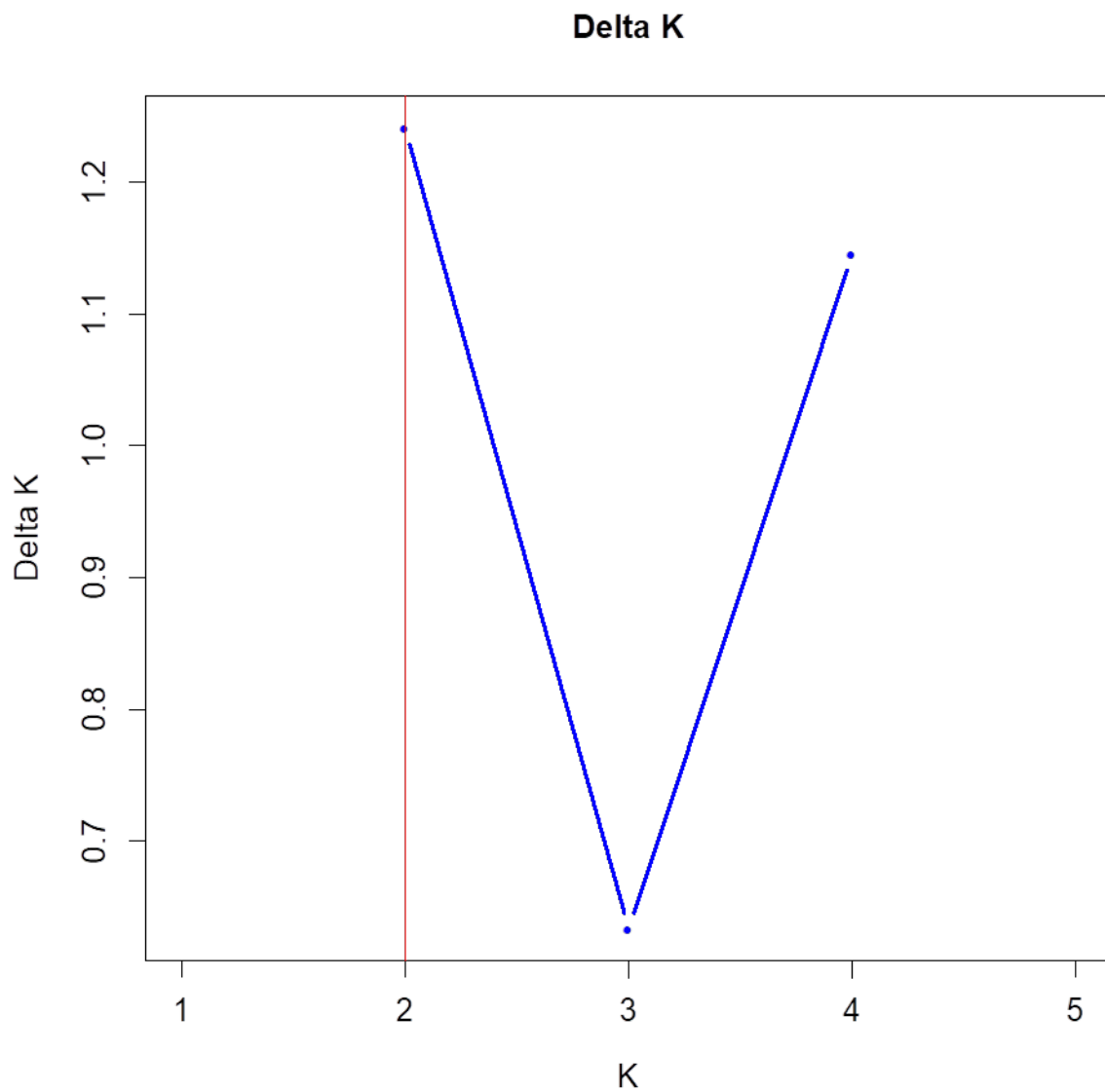


Figure 3.3.2: Results from Structure Selector (Li and Liu, 2018) showing the number of populations as $K = 2$ based on 66 populations of *Cortaderia selloana* in South Africa, using eight microsatellite primers and the Evanno method according to Earl and Holdt (2012).