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Alien and invasive Poaceae weed species in Madagascar: listing and recommendations

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Recent research has improved the understanding of the Poaceae family in Madagascar, particularly in terms of taxonomy. These studies have facilitated better identification and classification of species. However, little attention has been given to alien and invasive Poaceae weed species, despite their important role in ecological dynamics. This gap highlights the need to investigate the invasive potential of this plant family, which can significantly impact Madagascar's ecosystems. In this study, we aim to advance the understanding of Poaceae invasions by reviewing existing data and highlighting key insights to support Madagascar's invasive species management. We developed a comprehensive checklist of 154 Poaceae weeds and/or alien species based on literature reviews and online databases to ensure accuracy and comprehensiveness. Our goal was to categorise these species into groups with three distinct management recommendations: prohibited species, species that need to be monitored and those considered harmless. Each of these categories was defined based on its estimated ecological impact and invasiveness potential. Among the 154 species assessed, we confirmed the presence of 56 species introduced to Madagascar and identified one species that we suggest should be prohibited in Madagascar. Based on our assessment, we propose a precautionary approach for species that are not yet invasive but pose a threat. Additionally, we highlight species that should be subject to risk analysis to assess their invasive potential. By developing these recommendations, we hope to assist in the creation of effective strategies for managing Poaceae invasions in Madagascar and to support broader conservation efforts.

Keywords: category, checklist, introduction, Madagascar, non-native species, Poaceae, weeds.

Introduction

Madagascar relies heavily on smallholder agriculture, with 60% of agricultural production recently used for household self-consumption (World Bank Group 2017). In this context, invasive weeds currently cause greater yield losses than any other known factor (Oerke 2006). Invasive and weedy plant species can cause great harm in ecosystems rich in endemic species, such as Madagascar. The United States suffers $1.1–$120 billion annually in economic losses due to invasive alien species (OTA 1993; Pimentel et al. 2005) while economic losses amounted to R9.6 billion in South Africa (McCulloch-Jones et al. 2024). The concepts of alien species and invasive species are often confused, although they refer to distinct ecological realities and require a clear understanding of species distributions. An alien species, also known as a non-native or non-indigenous species, is one that occurs in an area outside of its natural geographical range due to direct or indirect human intervention (Blackburn et al. 2011). This movement involves the species overcoming natural biogeographical barriers that it would not have crossed on its own. An invasive species, on the other hand, is a subset

of alien species. It not only establishes self-sustaining populations that persist over multiple generations but also produces fertile offspring and spreads across new areas. This expansion often leads to significant negative impacts, both ecologically, such as disrupting native ecosystems and outcompeting local species, and economically, through agricultural losses, increased management costs and environmental degradation. (Lisan 2014; Randall 2017). As ecological pioneers, native and locally endemic grasses can also cause negative impacts or become weeds, often leading to confusion regarding their origins and correct terminology.

In Madagascar, the introduction of cultivated plant species is a significant driver of invasive species spread. There are an estimated 1 157 introduced plants currently listed: 611 cultivated, plus 546 naturalised of which 101 are invasive (Perrier de la Bâthie 1931; Kull et al. 2012), including 71 Poaceae species. In addition, a preliminary study outlining a list of 70 invasive plant species, along with practices for controlling and managing them, was conducted by Lisan (2014) in Madagascar; however, he referred to only four species from the Poaceae family. Many alien plants initially introduced for agriculture, forestry or ornamental purposes in the early 20th century have escaped from cultivation, thus they became weeds when they escaped from their initial growing site, and became invasive, threatening crops and native ecosystems. For instance, Kull et al. (2015) noted that species like *Rubus alceifolius* Poir. (Moluccan bramble) and *Miconia crenata* (Vahl) Michelang. (Koster's curse), first introduced for cultivation, have become widespread invaders in eastern Madagascar, colonising fallow lands and forest edges. Furthermore, GRIIS Madagascar (https://www.gbif.org/dataset/baf86ad8-24ad-4603-a723-dcc9647846da#description; Randrianizahana et al. 2020) highlights 902 invasive plant species records that, after being introduced for cultivation, have established themselves outside of cultivation and exhibit invasive behaviour. However, the current biosecurity policy in Madagascar is mainly focused on the introduction and management of Genetically Modified Organisms (Randriamoria 2019), plant species and 100 useful imported plants, and harmful organisms prohibited for importation, especially insects, bacteria or viruses (MINAE 2002).

While many reforestation efforts in Madagascar are careful to use non-invasive and native trees (Di Sacco et al. 2021), the awareness of the management needs of herbaceous plants such as the family Poaceae are not yet considered. Within the framework of the Convention on Biological Diversity (CBD), Madagascar has committed itself to continue actions for the conservation of its natural resources and to implement recommendations for better management of its biodiversity, contributing indirectly to the preservation of the world's biological heritage. Since 2010, the Royal Botanic Gardens Kew–Madagascar (RBG Kew) grass projects have been gathering a comprehensive body of knowledge on Madagascar's Poaceae, which is well recognised locally and is already applied to grassland conservation and pasture management initiatives (Solofondranohatra et al. 2018, 2020; Randriamanalina et al. 2024). This study mobilises the accumulated knowledge to help Madagascar understand alien Poaceae weeds, control them and prepare to mitigate future challenges. Currently, there are not many updated datasets available that list all invasive Poaceae species in Madagascar, and a significant quantity of outdated and erroneous information has been propagated. However, a recent publication by Rabarivola et al. (2019) provided distribution data of 522 Poaceae species and GRIIS (Randrianizahana et al. 2020) listed 152 alien Poaceae species. These preliminary results gave us an initial understanding of both the species taxonomy and their introduction status, enabling us to build a checklist of alien and invasive Poaceae weed species, to investigate the invasive potential of the Poaceae family and to advance understanding of their invasions.

Method

Literature review

The current checklist is based on taxonomic studies conducted in Madagascar for multiple purposes, including taxonomic revisions, weed identification, forage and cultivated species, alien species assessment and livelihood studies (Figure 1A).

The WIKTROP (Weed Identification and Knowledge in the Tropical and Mediterranean areas, https://portal.wiktrop.org/) online checklist and a list from Jean Augustin Randriamampianina's research (Randriamampianina 2017) were used as a baseline. To improve the inventory, we consulted other online databases: CABI (Centre for Agriculture and Bioscience, International, https://www.cabidigitallibrary.org/), POWO (Plants of the World Online, https://powo.science.kew.org/), Tropicos (https://tropicos.org/home), books and major publications related to forage or pasture studies and introduced species in Madagascar (Perrier de la Bâthie 1931; Dufournet et al. 1959; Borget 1962; Bosser 1969; Kull et al. 2012; Lisan 2014; Randall 2017; Vorontsova et al. 2018). Madagascar's national and largest herbarium in Antananarivo (TAN, situated in the Parc Botanique et Zoologique de Tsimbazaza, PBZT), as well as the Royal Botanic Gardens Kew Poaceae project research data (BRAHMS), were consulted as sources of additional data. New species records were also added in the light of recent studies: a revision of *Digitaria* in Madagascar (MacKinnon et al. in press) and a photographic field guide of Madagascar grasses (Rakotomalala et al. 2025).

In order to update species names and carry out quality control, only records confirmed by Poaceae specialists, herbarium specimens from TAN, or high quality fully verifiable photographic evidence (iNaturalist, https://www.inaturalist.org/, and personal observations from experts: Maria Vorontsova, Olinirina Nanjarisoa Prisca, Nantenaina Rakotomalala, Jean Augustin Randriamampianina, Fenitra Randrianarimanana) were retained for reconciliation. We checked and assigned the Poaceae names to accepted names with the author names from POWO. Given the lack of attention given to this family in Madagascar, it is likely

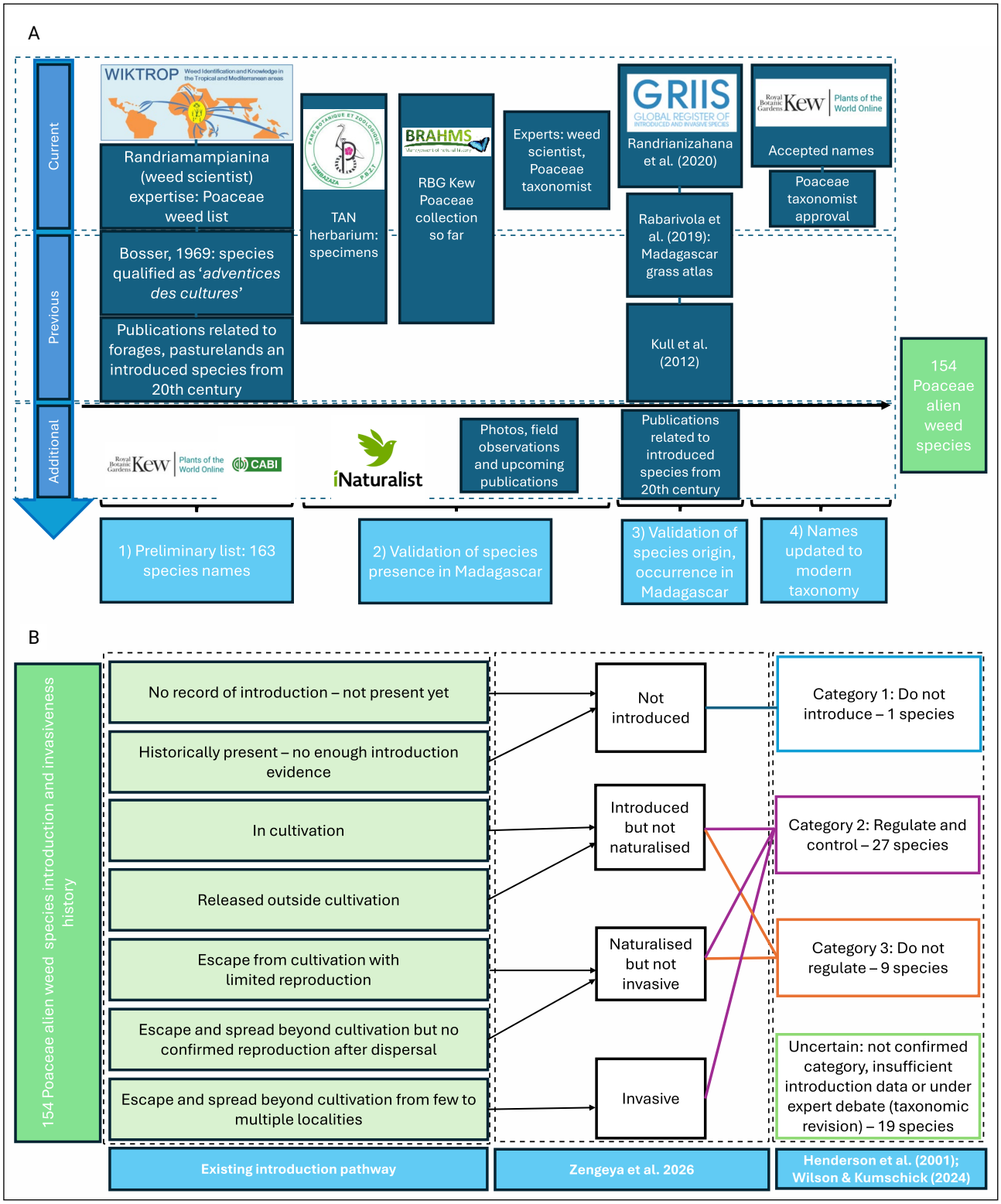

Figure 1. Workflow of this study compiling the alien and invasive Poaceae weed species. A, data collection from various sources (current, previous and additional) to compilation: from literature review to expert confirmation; B, introduction status and category assignment based on occurrence records and introduction evidence, adapted from Zengeya et al. (2026).

that there are further unrecorded species, which we were not able to include in our list.

Due to the variability in how naturalised and invasive species are defined across studies, it is essential to consult reliable sources. We have chosen to rely on what we believe are the four most recent and accurate databases for Madagascar: the WIKTROP website for weed species, the Madagascar Grass Atlas (Rabarivola et al. 2019) for the species native occurrence, Bosser (1969) reference volume for weed and alien species introduction, and the GRIIS-Madagascar (https://www.gbif.org/dataset/baf86ad8-24ad-4603-a723-dcc9647846da#description) for the 152 invasive alien species names of Poaceae, including synonyms (Supplementary Material 1).

Species status and categorisation

While the introduction and origins of Poaceae species are still ambiguous in Madagascar, the listing method used by Zengeya et al. (2026) and Blackburn et al. (2011) was followed to suggest a preliminary introduction status based on the available evidence and historical records. However, it is worth mentioning that the data available for Madagascar are dramatically smaller than their South African equivalent, since little recording of Poaceae has been carried out across Madagascar to date. The lack of evidence and data availability may also indicate the species' non-viability or a very slow rate of spread. Only the species mentioned as introduced in Madagascar by Rabarivola et al. (2019) were retained in the final list. The species list was then classified according to the four statuses of introduction established by Zengeya et al. (2025) and Blackburn et al. (2011). The criteria range from 'not having record of introduction or was historically present but with no presence evidence', 'introduced but not naturalised', 'naturalised but not invasive' to 'invasive' (Figure 1B). Regarding the introduction status, species considered naturalised by Kull et al. (2012) were included without further evaluation. Only those absent from the oldest and newest publications were assessed using introduction records, based on the literature review.

To assign a recommended legal status to recommend future management, we adapted the Henderson (2001) and Wilson and Kumschick (2024) methodology with three main species categories (Figure 1B). Our species categorisation is based on both the history of introduction and on the overall perception of the weed scientist regarding each species in the different regions where inventories have been conducted to date. Category 1 (do not introduce) are taxa that have not been recorded in Madagascar but already have a high invasion potential elsewhere and ideally should not be introduced or must be prohibited. All the taxa we listed under Categories 2 (regulate and control) and 3 (do not regulate) are, or were at one point, present in Madagascar. The recommended Category 2 designation refers to taxa that should be controlled under permit, as they are likely to arrive and may pose an unacceptable threat; for those already present, they are allowed but require monitoring to prevent further spread and should require a permit for any future accidental importation. Category 3 includes taxa that are ornamentally used and may no longer be planted in Madagascar, or those whose spread is slow and does not pose a major problem. Taxa which are not mentioned were not considered within our workflow, absent from all the sources assessed. These apparently absent species can of course be present in Madagascar with no specialist awareness of their presence, and no good quality collections with specialist-verified identifications. The 'Uncertain' category refers to species for which specialists have reached a consensus that available data are insufficient or currently under debate such as taxonomic revision or the need of species datation. These taxa cannot yet be confidently assigned to a definitive status.

Results

A total of 155 accepted names, 94 identified as weeds from WIKTROP and 137 from this paper, 89 listed as alien according to GRISS (Supplementary Material Tables S1 & S2), which are the most recent inventories, in addition to investigations carried out by Malagasy grass taxonomists and weed scientists to date represented by the third column entitled 'This paper', were gathered. Among the refined and matched list (Supplementary Material Table S2), and based on the three studies, 65 species are simultaneously classified as both weeds and alien species, 32 by two of the studies – meaning frequently observed, and 57 by only one – implying rare occurrence or novelty.

Supplementary Material Table S2 was used as a broad baseline for detailed categorisation in accordance with Rabarivola et al. (2019)'s 'species native occurrences', which were also built on Bosser (1969), except *Arundo donax*, which was [apparently erroneously] recorded once on the iNaturalist website recently. We have prioritised the 56 marked species as introduced based on Rabarivola et al. (2019) and identified as weeds by at least one source among Bosser (1969), WIKTROP, or inventories by weed scientists and taxonomists (Supplementary Material Tables S1 & S2). These species were retained and considered for the recommendations presented in Table 1. The reduction of the final list is mainly based on data availability, such as native occurrence and lack of new species records. Some records reflected incorrect plant identifications, and some reflected twentieth century agricultural trials of grasses that did not escape from cultivation. The species list includes both those simultaneously identified as weeds and alien species by two or three studies, as well as

Table 1. Confirmed alien and invasive Poaceae weed species list based on native occurrence from Rabarivola et al. (2019) coupled with the presumed introduction status and the recommended regulatory group based on the listing method used by Henderson (2001), Wilson & Kumschick et al. (2024) and Zengeya et al. (2026), listed alphabetically based on the POWO accepted names column. The 'NA' category means not available or listed in the study. 'Uncertain' indicates those that were doubtful due to insufficient data. *Oryza perennis* was previously considered to be a taxon distinct from cultivated rice; these records are likely to refer to populations of what is now considered *Oryza sativa*, cultivated rice, the populations of which sometimes display unusual traits, which do not persist and do not lead to speciation events. The information is also provided in a spreadsheet (Supplementary Material Table S1). Details of the process are illustrated in Figure 1, with corresponding metadata available in Supplementary Material 1

Species names		Weed status			Native occurrence	Nativity	Distribution and introduction		Degree of establishment	Presumed introduction (Zengeya et al. 2026)	Regulatory recommendation (Henderson 2001; Wilson & Kumschick 2024)
Species names found in sources	**POWO accepted names**	**WIKTROP list**	**Bosser (1969)**	**This paper**	**Rabarivola et al. (2019)**	**GRIIS/GBIF (Randrianizahana et al. 2020)**	**Distribution to Madagascar (POWO)**	**Bosser (1969)**	**Kull et al. (2012)**		
Arundo donax	*Arundo donax* L.	Weed	NA	NA	NA	Alien	Introduced	NA	Naturalised	Not introduced	Do not introduce
Anthoxanthum odoratum	*Anthoxanthum odoratum* L.	Weed	NA	NA	Macaronesia, Europe to Mongolia, NW Africa	Alien	Introduced	From La Réunion	Naturalised	Naturalised but not invasive	Do not regulate
Avena sativa	*Avena sativa* L.	Weed	NA	NA	Cultigen from W Asia	Alien	NA	NA	Cultivated	Introduced but not naturalised	Regulate and control
Axonopus compressus	*Axonopus compressus* (Sw.) P.Beauv.	Weed	Weed	Weed	Tropical & subtropical America	Alien	Introduced	From America	NA	Uncertain	Regulate and control
Cenchrus biflorus	*Cenchrus biflorus* Roxb.	Weed	Weed	Weed	Africa to NW India	Alien	Native	From Africa	NA	Uncertain	Regulate and control
Cenchrus echinatus	*Cenchrus echinatus* L.	Weed	Weed	Weed	Central & S U.S.A. to tropical & subtropical America	Alien	Introduced	From America	NA	Uncertain	Regulate and control
Chloris gayana	*Chloris gayana* Kunth	Weed	NA	NA	Macaronesia, tropical & southern Africa, Arabian Peninsula	Alien	Introduced	Introduced for meadow purposes	NA	Introduced but not naturalised	Regulate and control
Chloris pycnothrix	*Chloris pycnothrix* Trin.	Weed	Weed	Weed	Africa to SW Arabian Peninsula, S tropical America	Alien	Native	Uncertain	NA	Uncertain	Uncertain

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Chloris virgata	*Chloris virgata* Sw.	Weed	Weed	Weed	Temperate & subtropical America	Alien	Introduced	NA	NA	Uncertain	Regulate and control
Coix lacryma-jobi	*Coix lacryma-jobi* L.	Weed	NA	NA	Indian subcontinent to Taiwan and Peninsula Malaysia	Alien	Introduced	From tropical Asia, cultivated for forage purposes	Naturalised	Naturalised but not invasive	Do not regulate
Cynodon dactylon	*Cynodon dactylon* (L.) Pers.	Weed	Weed	Weed	Temperate & subtropical Old World to Australia	Alien	Native	Uncertain	Highly invasive	Invasive	Uncertain
Digitaria bicornis	*Digitaria bicornis* (Lam.) Roem. & Schult.	Weed	Weed	Weed	W Indian Ocean, tropical & subtropical Asia to N Australia	Alien	Native	Tropical regions	NA	Uncertain	Uncertain
Digitaria debilis	*Digitaria debilis* (Desf.) Willd.	NA	Weed	Weed	S Europe to Africa	NA	Native	Africa & Madagascar	NA	Uncertain	Uncertain
Digitaria didactyla	*Digitaria didactyla* Willd.	NA	NA	Weed	Malawi to Mozambique , W Indian Ocean	NA	Native	Tropical regions	NA	Uncertain	Uncertain
Digitaria horizontalis	*Digitaria horizontalis* Willd.	Weed	Weed	Weed	Tropical & subtropical America, Cape Verde, W & W central tropical Africa	Alien	Introduced	From America and Africa	NA	Uncertain	Regulate and control

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Digitaria radicosa	*Digitaria radicosa* (J.Presl) Miq.	Weed	Not listed	Weed	Tropical & subtropical Asia to Pacific	Alien	Introduced	NA	NA	Uncertain	Uncertain
Digitaria sanguinalis	*Digitaria sanguinalis* (L.) Scop.	NA	NA	Weed	Mediterranean to central Asia and Malesia	NA	NA	NA	Naturalised	Introduced but not naturalised	Uncertain
Digitaria violascens	*Digitaria violascens* Link	NA	Weed	Weed	Tropical & subtropical Asia to N & E Australia	NA	Introduced	From tropical America and Asia	NA	Uncertain	Uncertain
Echinochloa pyramidalis	*Echinochloa pyramidalis* (Lam.) Hitchc. & Chase	Weed	NA	Weed	Africa to Arabian Peninsula	Alien	Native	From tropical Africa	NA	Uncertain	Uncertain
Echinochloa stagnina	*Echinochloa stagnina* (Retz.) P.Beauv.	Weed	Weed	Weed	Africa, tropical Asia	Alien	Native	Africa & Asia	NA	Uncertain	Regulate and control
Enneapogon cenchroides	*Enneapogon cenchroides* (Licht.) C.E.Hubb.	NA	Weed	Weed	Africa to India	NA	Native	Uncertain	NA	Uncertain	Uncertain
Eragrostis aspera	*Eragrostis aspera* (Jacq.) Nees	Weed	Weed	Weed	Africa, Arabian Peninsula, S India, Indo-China	Alien	Native	Africa & Asia	NA	Uncertain	Uncertain
Eragrostis cylindriflora	*Eragrostis cylindriflora* Hochst.	Weed	Weed	Weed	Africa	Alien	Introduced	NA	NA	Uncertain	Uncertain

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Species names found in sources	**POWO accepted names**	**WIKTROP list**	**Bosser (1969)**	**This paper**	**Rabarivola et al. (2019)**	**GRIIS/GBIF (Randrianizahana et al. 2020)**	**Distribution to Madagascar (POWO)**	**Bosser (1969)**	**Kull et al. (2012)**		
Eragrostis unioloides	*Eragrostis unioloides* (Retz.) Nees ex Steud.	Weed	NA	NA	Tropical & subtropical Asia to N & E Queensland	NA	Introduced	NA	NA	Uncertain	Uncertain
Hyparrhenia rufa	*Hyparrhenia rufa* (Nees) Stapf	NA	NA	Weed	Tropical & southern Africa, W Indian Ocean, S central China to Indo-China	NA	Native	From India & Australia, introduced in Madagascar	Invasive	Invasive	Regulate and control
Heteropogon contortus	*Heteropogon contortus* (L.) P.Beauv. ex Roem. & Schult.	NA	NA	Weed	Tropical & subtropical to S central Europe	Alien	Native	From tropical regions	Invasive	Invasive	Regulate and control
Imperata cylindrica	*Imperata cylindrica* (L.) Raeusch.	Weed	NA	Weed	Mediterranean to Africa and Afghanistan	Alien	Native	Tropical regions & Old World	Naturalised, highly invasive	Invasive	Regulate and control
Ischaemum rugosum	*Ischaemum rugosum* Salisb.	Weed	Weed	Weed	Tropical Africa, tropical & subtropical Asia to W Pacific	Alien	Introduced	From Asia, introduced 50 years ago in Diego Suarez	Highly invasive	Invasive	Regulate and control
Panicum maximum	*Megathyrsus maximus* (Jacq.) B.K.Simon & S.W.L.Jacobs	Weed	NA	Weed	Tropical & southern Africa, W Indian Ocean, Arabian Peninsula	Alien	Native	From tropical Africa	NA	Uncertain	Regulate and control
Melinis repens	*Melinis repens* (Willd.) Zizka	Weed	NA	Weed	Africa to Arabian Peninsula	Alien	Native	Uncertain	Invasive	Invasive	Regulate and control

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Brachiaria eruciformis	*Moorochloa eruciformis* (Sm.) Veldkamp	Weed	Weed	Weed	Mediterranean to Indo-China and Africa	Alien	Native	Mediterranean, Asia & Africa	NA	Uncertain	Uncertain
Oryza perennis	*Oryza sativa* L.	Weed	NA	NA	Cultigen from China (*O. sativa*)	Alien (*O. sativa*)	Introduced (*O. sativa*). No more data related to *O. perennis*	NA	NA	Not introduced as *O. perennis*	Do not regulate
Panicum brevifolium	*Panicum brevifolium* L.	Weed	Weed	Weed	Tropical Africa, W Indian Ocean, tropical & subtropical Asia	NA	Native	Africa & Asia	NA	Uncertain	Uncertain
Paspalum conjugatum	*Paspalum conjugatum* P.J.Bergius	Weed	Weed	Weed	Tropical & subtropical America	Alien	Introduced	From tropical America	Naturalised, invasive	Invasive	Regulate and control
Paspalum dilatatum	*Paspalum dilatatum* Poir.	Weed	NA	NA	SE & S Brazil to S South America	Alien	Introduced	From South America, naturalised in the E and centre	Naturalised	Naturalised but not invasive	Regulate and control
Paspalum paniculatum	*Paspalum paniculatum* L.	Weed	Weed	Weed	Mexico to tropical America	Alien	Introduced	From America	Naturalised	Naturalised but not invasive	Regulate and control
Paspalum vaginatum	*Paspalum vaginatum* Sw.	Weed	NA	Weed	Tropical & subtropical America	Alien	Introduced	NA	NA	Invasive	Regulate and control
Paspalum virgatum	*Paspalum virgatum* L.	Weed	NA	NA	Tropical & subtropical America	Alien	Introduced	From America	Cultivated	Introduced but not naturalised	Regulate and control

Table 1. Confirmed alien and invasive Poaceae weed species list based on native occurrence from Rabarivola et al. (2019) coupled with the presumed introduction status and the recommended regulatory group based on the listing method used by Henderson (2001), Wilson & Kumschick et al. (2024) and Zengeya et al. (2026), listed alphabetically based on the POWO accepted names column. The 'NA' category means not available or listed in the study. 'Uncertain' indicates those that were doubtful due to insufficient data. Oryza perennis was previously considered to be a taxon distinct from cultivated rice; these records are likely to refer to populations of what is now considered Oryza sativa, cultivated rice, the populations of which sometimes display unusual traits, which do not persist and do not lead to speciation events. The information is also provided in a spreadsheet (Supplementary Material Table S1). Details of the process are illustrated in Figure 1, with corresponding metadata available in Supplementary Material 1 (continued)

Species names		**Weed status**			**Native occurrence**	**Nativity**	**Distribution and introduction**		**Degree of establishment**	**Presumed introduction (Zengeya et al. 2026)**	**Regulatory recommendation (Henderson 2001; Wilson & Kumschick 2024)**
Species names found in sources	**POWO accepted names**	**WIKTROP list**	**Bosser (1969)**	**This paper**	**Rabarivola et al. (2019)**	**GRIIS/GBIF (Randrianizahana et al. 2020)**	**Distribution to Madagascar (POWO)**	**Bosser (1969)**	**Kull et al. (2012)**		
Phragmites mauritianus	*Phragmites mauritianus* Kunth	NA	NA	Weed	Tropical & southern Africa, W Indian Ocean	NA	Native	NA	NA	Uncertain	Do not regulate
Poa annua	*Poa annua* L.	Weed	NA	Weed	Temp. Old World to tropical mountains	Alien	Introduced	Introduced in the Highlands	Naturalised	Naturalised but not invasive	Regulate and control
Polypogon monspeliensis	*Polypogon monspeliensis* (L.) Desf	Weed	NA	Weed	Macaronesia, W & S Europe to Temp. E Asia, N Africa to Tanzania	NA	NA	NA	NA	Uncertain	Do not regulate
Schizachyrium exile	*Schizachyrium exile* (Hochst.) Pilg.	NA	Weed	Weed	Tropical & southern Africa, Indian subcontinent to Myanmar	NA	Introduced	Introduced	NA	Uncertain	Uncertain
Sorghum arundinaceum	*Sorghum bicolor* subsp. *verticilliflorum* (Steud.) de Wet ex Wiersema & J.Dahlb.	Weed	NA	NA	Cultigen from African Sahel	Alien	Native	NA	Introduced	Introduced but not naturalised	Do not regulate
Sorghum verticilliflorum	*Sorghum bicolor subsp. verticilliflorum* (Steud.) de Wet ex Wiersema & J.Dahlb.	NA	NA	Weed	Cultigen from African Sahel	NA	Native	NA	NA	Introduced but not naturalised	Do not regulate

Table 1. Confirmed alien and invasive Poaceae weed species list based on native occurrence from Rabarivola et al. (2019) coupled with the presumed introduction status and the recommended regulatory group based on the listing method used by Henderson (2001), Wilson & Kumschick et al. (2024) and Zengeya et al. (2026), listed alphabetically based on the POWO accepted names column. The 'NA' category means not available or listed in the study. 'Uncertain' indicates those that were doubtful due to insufficient data. Oryza perennis was previously considered to be a taxon distinct from cultivated rice; these records are likely to refer to populations of what is now considered Oryza sativa, cultivated rice, the populations of which sometimes display unusual traits, which do not persist and do not lead to speciation events. The information is also provided in a spreadsheet (Supplementary Material Table S1). Details of the process are illustrated in Figure 1, with corresponding metadata available in Supplementary Material 1 (continued)

Species names		**Weed status**			**Native occurrence**	**Nativity**	**Distribution and introduction**		**Degree of establishment**	**Presumed introduction (Zengeya et al. 2026)**	**Regulatory recommendation (Henderson 2001; Wilson & Kumschick 2024)**
Species names found in sources	**POWO accepted names**	**WIKTROP list**	**Bosser (1969)**	**This paper**	**Rabarivola et al. (2019)**	**GRIIS/GBIF (Randrianizahana et al. 2020)**	**Distribution to Madagascar (POWO)**	**Bosser (1969)**	**Kull et al. (2012)**		
Sorghum halepense	*Sorghum halepense* (L.) Pers.	NA	NA	Weed	Macaronesia to central Asia and Indo-China	Alien	Introduced	From Mediterranean (Asia to India)	NA	Introduced but not naturalised	Do not regulate
Sporobolus africanus	*Sporobolus africanus* (Poir.) Robyns & Tournay	Weed	Weed	Weed	Nigeria to Ethiopia and southern Africa, Arabian Peninsula, Sri Lanka	Alien	Introduced	Introduced	NA	Uncertain	Uncertain
Sporobolus indicus	*Sporobolus indicus* (L.) R.Br.	Weed	NA	NA	Tropical & subtropical America	NA	Introduced	NA	NA	Uncertain	Uncertain
Sporobolus pyramidalis	*Sporobolus pyramidalis* P.Beauv.	NA	Weed	Weed	Tropical & subtropical America, Africa to Arabian Peninsula	Alien	Native	NA	Naturalised	Naturalised but not invasive	Regulate and control
Stenotaphrum dimidiatum	*Stenotaphrum dimidiatum* (L.) Brongn.	Weed	Weed	Weed	Coastal Kenya to southern Africa, W Indian Ocean, Indian subcontinent to Peninsula Malaysia	Alien	Native	NA	Invasive	Uncertain	Do not regulate
Themeda quadrivalvis	*Themeda quadrivalvis* (L.) Kuntze	Weed	Weed	Weed	Indian subcontinent to N Thailand, Andaman Islands	Alien	Introduced	From Asia , introduced in Diego Suarez	Invasive	Uncertain	Regulate and control

Table 1. Confirmed alien and invasive Poaceae weed species list based on native occurrence from Rabarivola et al. (2019) coupled with the presumed introduction status and the recommended regulatory group based on the listing method used by Henderson (2001), Wilson & Kumschick et al. (2024) and Zengeya et al. (2026), listed alphabetically based on the POWO accepted names column. The 'NA' category means not available or listed in the study. 'Uncertain' indicates those that were doubtful due to insufficient data. Oryza perennis was previously considered to be a taxon distinct from cultivated rice; these records are likely to refer to populations of what is now considered Oryza sativa, cultivated rice, the populations of which sometimes display unusual traits, which do not persist and do not lead to speciation events. The information is also provided in a spreadsheet (Supplementary Material Table S1). Details of the process are illustrated in Figure 1, with corresponding metadata available in Supplementary Material 1 (continued)

Species names		**Weed status**			**Native occurrence**	**Nativity**	**Distribution and introduction**		**Degree of establishment**	**Presumed introduction (Zengeya et al. 2026)**	**Regulatory recommendation (Henderson 2001; Wilson & Kumschick 2024)**
Species names found in sources	**POWO accepted names**	**WIKTROP list**	**Bosser (1969)**	**This paper**	**Rabarivola et al. (2019)**	**GRIIS/GBIF (Randrianizahana et al. 2020)**	**Distribution to Madagascar (POWO)**	**Bosser (1969)**	**Kull et al. (2012)**		
Tragus berteronianus	*Tragus berteronianus*	NA	Weed	Weed	Africa, Arabian Peninsula to China	NA	Native	NA	NA	Uncertain	Uncertain
Brachiaria brizantha	*Urochloa brizantha* (A.Rich.) R.D.Webster	Weed	NA	NA	Tropical & South Africa, West Indian Ocean, SW Arabian Peninsula	NA	Native	From Africa	NA	Introduced but not naturalised	Regulate and control
Brachiaria decumbens/ Brachiaria ruziziensis	*Urochloa eminii* (Mez) Davidse	Weed	NA	NA	Ivory Coast to Kenya and Zambia	NA	Introduced	From Congo for forage purposes	NA	Introduced but not naturalised	Regulate and control
Brachiaria mutica/ Panicum purpurascens	*Urochloa mutica* (Forssk.) T.Q.Nguyen	Weed	NA	NA	Sahara to Angola, N Africa to Syria, SW Arabian Peninsula	NA	Introduced	From Africa	NA	Introduced but not naturalised	Regulate and control
Brachiaria reptans	*Urochloa reptans* (L.) Stapf	Weed	Weed	Weed	Arabian Peninsula, Afghanistan to Pacific	NA	Introduced	NA	NA	Uncertain	Regulate and control
Brachiaria umbellata	*Urochloa umbellata* (Trin.) Oulo, Zon & Sosef	Weed	NA	Weed	Tanzania to S tropical Africa, W Indian Ocean	Alien	Native	From Mascarene islands, Comoros	NA	Uncertain	Regulate and control

those mentioned by only one. A total of 26 species has been assigned an adapted introduction status following reliable introduction pathways, and 37 to Henderson (2001) category suggestions. No Poaceae species have so far been assessed through a risk assessment in Madagascar.

Taxa that were doubtful were added in the 'Uncertain' category (Figure 1B, Table 1), with NA for those which were not recorded in the study. Most species have been introduced for forage and crop cultivation purposes.

Discussion

It is important to emphasise that the listing presented in Table 1 is only a preliminary data compilation, with much remaining unknown, especially related to high uncertainty around native versus introduced status. The assignments of native versus introduced status are particularly challenging to confirm in the absence of population genetic studies.

Listing

The majority of alien plants currently established in Madagascar, which were originally introduced for purposes such as food, fiber or ornamentation, as illustrated by the 21 introduced forage Poaceae species in the beginning of 20th Century (Dufournet 1959) or four varieties cultivated as forages (FOFIFA & FIFAMANOR 2010), have been assigned to watch (Category 2) or not to worry lists (Category 3) (Henderson 2001; NEM:BA 2020). It is important to note that the list compiled in this study is not exhaustive and represents only a general overview of the Poaceae species mentioned as introduced or weedy. Some species reported in publications may not be included here, e.g., if they were absent from most of the databases, or if voucher specimens were not made, were not preserved, were not easily accessible to our team, or were not sufficiently informative for identification to species level. This is particularly true for some forage species introduced from the 1940s onwards, which were not subject to weed status checks such as *Eragrostis tef* (Zuccagni) Trotter, *E. superba* Peyr., *Zea mexicana* (Schrad.) Kuntze (Dufournet 1959; Borget 1962), or forage varieties that are not included in the online database such as POWO: *Pennisetum purpureum* var. *kisozi*, *P. purpureum* à collets rouges, *P. purpureum* senso stricto (Borget 1962; Granier 1972) but should be included under *Pennisetum purpureum* Schumach., synonym of *Cenchrus purpureus* (Schumach.) Morrone. Among the 71 introduced Poaceae species identified by Kull et al. (2012), 19 are classified as weed species, and the presence of *Arundo donax* L. in Madagascar mentioned by Kull is not confirmed. No herbarium specimens are available and the one potential record from iNaturalist (https://www.inaturalist.org/observations/268261948) is doubtful with insufficient morphological detail available in the photographs. Nevertheless, *Arundo donax* was included in the list of prohibited species due to its aggressive spread and its classification as a major invasive species in South Africa (Henderson 2001; Canavan et al. 2017), indicating a high potential to invade Madagascar if no control measures are implemented. *Imperata cylindrica* (L.) Raeusch. and *Urochloa umbellata* (Trin.) Oulo, Zon & Sosef are also among the potential invasive plant threats Madagascar may face in the future, which were not assessed by Lisan (2014) due to lack of time. Even though *Urochloa umbellata* was listed as native by Vorontsova (2022) genetic data remain unavailable.

The complexity of studying this family may have led to an accumulation of errors broadly perpetuated across the literature (Vorontsova 2018; Randrianarimanana et al. 2024). The status of some species considered to be 'alien' by GRIIS and Perrier de la Bâthie (1931) has been challenged by recent studies, like the case of *Heteropogon contortus* (L.) P.Beauv. ex Roem. & Schult. and *Themeda quadrivalvis* (L.) Kuntze confirmed as native to Madagascar by DNA sequence and phylogenetic studies (Arthan et al. 2021), undermining their cited alien and invasive status (Lisan 2014). Another illustrative case concern a grass taxon whose nomenclature was revised in accordance with the 2024 updates to the International Code of Nomenclature (May & Hawksworth 2024). The revised name has not yet been integrated into platforms such as GBIF or WIKITROP, while major databases like POWO and IPNI either omit the taxon entirely (including as synonym) or have discontinued the use of the now-banned historical names. This situation underscores the persistence of nomenclatural inconsistencies across major botanical databases and led us not to include some species in the final list.

Scientific names often change following discoveries or taxonomic work, but major biodiversity databases like the ones used here may not immediately reflect the updates, leading to apparent absences or search errors (Franz & Thau 2010). Conversely, some species are considered harmful weeds by farmers but are infrequently recorded in databases due to poor documentation or only a small number of recent records. The tricky-to-identify *Digitaria ternata* (A.Rich.) Stapf is a native species from Africa, South and southeast Asia, and a serious weed in Guinea, China and Vietnam (Boonsuk et al. 2016), and was recorded in the highlands of Madagascar by grass taxonomists only once in 2022, already causing significant damage to crops (Randrianarimanana et al. 2024). The easily recognisable *Polypogon monspeliensis* (L.) Desf. is already present in Madagascar, sold in flower markets, while causing harm to rice fields in the mid-western part of Madagascar (Fenitra Randrianarimanana, personal observation) but has also been poorly documented as such. It is obvious that

more work, risk assessment and recordings need to be done in Madagascar to improve the data available for future invasive species studies. Also, consideration must be given to climate change as the grass distributions may change depending on climate, hydrology and fires.

Management and legislation

In South Africa, invasive species are regulated under the National Environmental Management: Biodiversity Act's Alien and Invasive Species Regulations (NEM:-BA A&IS Regulations) that were first promulgated in 2014 and last updated in 2020 (Wilson & Kumschick 2024). In Madagascar, the regulations so far concern only harmful cryptogams prohibited for import if they are in a state of isolation or if they occur on certain plants or plant products (MINAE 2002). A national invasive alien species strategy has been developed in Mauritius, where the country wants to move from isolated, one-off actions to proactive, planned and collaborative management to better control invasive species (Mauremootoo et al. 2019). For Réunion Island, there is a dedicated online platform for 338 invasive plants led by GEIR (Groupe Espèces Invasives de La Réunion) where the involvement of everyone against invasive species is recommended, and public and operational programmes for the control of invasive species are established (https://www.especesinvasives.re/especes-invasives/liste-des-especes-flore/, GEIR 2024). These approaches could be adapted for use in Madagascar by promoting and extending the WIKTROP website.

The Malagasy third national Convention on Biological Diversity (CBD) report stated that forage and agroforestry species are introduced without strict control, and the spread of some 'exotic' species is neither monitored nor assessed (MEDD 2005). There are many laws about plant genetic resources for food and farming, but they are not well organised and need to be updated and made consistent. Even though the management of 'exotic' and invasive species in Madagascar was also included in National Target 9 of the Sixth Conference of the Parties to the Convention on Biological Diversity (CBD) (MEDD 2019), the implementation of control measures remains insufficient to date. There are no appropriate provisions or strategies against the accidental introduction and spread of invasive alien species. Regarding forage crops, mostly introduced and selected over time, serving as genetic diversity banks for breeding, they are conserved using mainly in situ techniques like cloning or self-fertilisation, and seeds are stored and periodically regenerated to maintain viability, sometimes in botanical gardens (MINAE 2009). In order to preserve genetic integrity and prevent contamination, sites should be isolated from related crops or wild populations (Randriananiviarivony et al. 2021). It is also important to base it on ongoing assessments, with clear objectives and indicators that make evaluation easy and guide decisions (Ralimanana et al. 2022).

For the case of Poaceae weed species, there is no single precise control method available for these diverse plants; management relies on manual or chemical weeding and is limited to cultivated areas (Randriamampianina et al. 2017; Randrianarimanana et al. 2024). Even for Réunion Island, no grass species is yet on the list (GEIR 2024). Following the challenges of studying Poaceae species due to their minute floral structures (Vorontsova et al. 2018), the lack of biosecurity-related information is the second main reason why we were unable to establish regulatory recommendation for many of the species listed. In addition, we support the idea that the lack of complete scientific certainty should not be used as an excuse to delay taking effective measures to prevent environmental degradation (Randriamoria 2019). Given the number of potential new introductions, it is often impractical to manage invasions and weeds taxon by taxon. Instead, it is preferable to look at the risks posed by pathways and implement pathway-specific regulations and control measures (Woodford et al. 2016; Visser et al. 2017). Checklists such as this one can act as a starting point and for structuring planning discussions in workshops, as they help to pick actions objectively, considering suggestions from different people's expertise (Tye 2018). The next step can be turning the not-to-worry list into a safe list, as though it will require more scientific evidence and rigorous risk assessment for proposed taxa, they are relatively straightforward in terms of the set of criteria that are required (Kumschick et al. 2024). It is imperative to clearly define the rules that prevent a species from becoming invasive and to establish measures to ensure that these rules are followed.

Conclusion

This study represents the first comprehensive investigation of alien Poaceae weeds in Madagascar. By conducting a detailed, step-by-step evaluation and filtering of the species lists, it became evident just how challenging it is to work with this particular plant family. The complexity of categorising Poaceae species is highlighted by the variations observed between different research efforts. Notably, lists of Poaceae weeds and alien species differ significantly depending on the focus of the research, with higher numbers typically found in weed science and forage studies compared to those focusing on conservation, especially in terms of risk assessment. This discrepancy underscores the challenge of accurately assessing the invasive potential of these species. Species that have high data availability tend to be observed and recognised more frequently than those with limited information. This is a common trend in ecological research, where more well-documented species are often prioritised. However, it is important to

note that a restricted distribution or limited recording of a species might not mean fewer negative impacts or a lower threat. In fact, some species with limited geographic spread may still pose significant ecological or economic risks, which makes them difficult to assess fully based on available data alone. As of today, only a small number of researchers have shown a dedicated interest in studying the Poaceae family, particularly in the context of their invasive potential. This gap in research is not entirely surprising, given the complexity and significant diversity of the family. Nonetheless, some Poaceae species continue to remain a significant concern for weed scientists around the world, especially as their ability to spread and impact ecosystems grows as human-driven disturbance increases and the climate changes. Despite the limited attention in certain areas, progress is being made through continuous studies on pastures, taxonomic revisions and the development of photographic and online databases. These efforts are not only enhancing the accuracy of species identification but also ensuring that the most recent data are incorporated into ongoing research. The data collected in this study, particularly regarding the introduction of various grass species, provides a valuable foundation for future risk assessments of Poaceae species. This newly gathered information serves as a baseline for evaluating the potential risks posed by these species, contributing to a deeper understanding of their ecological impacts. Moreover, it addresses some of the current gaps in the available data, helping to build a more comprehensive and accurate picture of the situation. Looking ahead, we aim to publish a subsequent paper that will present more conclusive and refined data, surpassing the preliminary findings provided in the current study. This follow-up will offer a more detailed analysis, which is essential for the continued monitoring and management of Poaceae species in Madagascar. Furthermore, the effective management of alien and invasive Poaceae weed species is crucial not only for reducing their negative impact on native ecosystems but also for promoting the conservation and sustainable utilisation of Madagascar's unique flora. Addressing the challenges posed by invasive species will be a pivotal step in enhancing the overall ecological health and biodiversity of the region.

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Competing interests

The authors declare that they have no financial or personal relationship(s) that may have inappropriately influenced them in writing this article.

Authors' contributions

MSV, JAR, VMR, MR and NFHR designed the study. NFHR, NHR, JAR performed the study and collected data. NFHR and MSV checked species confirmation in Madagascar. NFHR, VMR and MSV wrote the manuscript.

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Data availability

The data that support the findings of this study are available in a supplementary file, but some data, such as new distributions, have to be requested from the corresponding author due to privacy or ethical restrictions.

Disclaimer

We confirm that the views expressed in the submitted article are our own and do not represent the official position of our institutions or funders.

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Supplementary material

Excel spreadsheet available online: http://dx.doi.org/10.38201/abc.v56.2.a6.

Supplementary Material 1

Table S1 is a raw list of Poaceae species names from GRISS Madagascar, WIKTROP and the current conducted study metadata. The 89 species names from the WIKTROP list, as well as the 152 species names from GRISS include synonym names, while the 154 species names from the current study have already been updated following the accepted names. The species names here are from weed scientists and grass taxonomists' investigations in different localities of Madagascar. The lists are ordered alphabetically and include native and alien species.

Table S2 is a refined list of Poaceae weed species versus alien, based on POWO, WIKTROP and investigations by Malagasy weed scientists and Poaceae taxonomists. The list is ordered alphabetically by the 56 matched and POWO accepted names, compiled with the origin, occurrence and distribution from Rabarivola et al. (2019), POWO, Bosser (1969) and Kull et al. (2012), as well as presumed introduction and suggested regulations based on Blackburn et al. (2011) and Henderson (2001). The NA category means absent from the list.