

Impact of alien grasses on the environment, biodiversity and crops in Iran

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Impact of alien grasses on the environment, biodiversity and crops in Iran

Abstract: The high number of alien grasses in Iran makes it necessary to prioritize species for mitigating their negative consequences on the environment and agricultural production. We classified 34 alien grasses in Iran based on the IUCN Environmental Impact Classification of Alien Taxa (EICAT-IUCN) to assess their risks on native species and mapped their distributions in Iran's ecological zones. We also discussed their impacts on agriculture and management options. *Rottboellia cochinchinensis*, *Paspalum distichum* and *Microstegium vimineum* have the potential to cause massive impacts, while *Cenchrus longispinus*, *Eragrostis curvula*, *Panicum repens*, *Paspalum urvillei*, *Cortaderia jubata* and *Phyllostachys reticulata* can cause major impacts on native species. Competition, transmission of disease and ecosystem structural impact accounted for over 49% of the mechanisms leading to environmental impacts. The Fisher's exact test indicates a significant association between the EICAT-IUCN score and life cycle. Of the 23 grasses invading crops, 60% have infested rice fields; and *P. repens*, *P. distichum*, *Paspalum dilatatum* and *Leptochloa chinensis* have the highest potential impact on yield losses (>60% in some cases in worldwide). *P. distichum* and *P. repens* can have the greatest potential impacts on both the environment and agriculture. Conservation priorities must be established to address the potential environmental impacts caused by alien grass species in Iran.

Keywords: ecological zone; EICAT-IUCN; invasion risk; naturalized grasses; mechanisms of impact; plant competition

Impacto de las gramíneas invasoras en el medio ambiente, la biodiversidad y los cultivos en Irán

Resumen: El elevado número de gramíneas invasoras en Irán hace necesario priorizar las especies para mitigar sus consecuencias negativas sobre el medio ambiente y la producción agrícola. Clasificamos 34 gramíneas invasoras en Irán basándonos en la Clasificación de Impacto Ambiental de Taxones Exóticos (EICAT-IUCN) de la UICN para evaluar sus riesgos sobre las especies autóctonas y cartografiamos su distribución en las zonas ecológicas de Irán. También analizamos sus repercusiones en la agricultura y las opciones de gestión. *Rottboellia cochinchinensis*, *Paspalum distichum* y *Microstegium vimineum* pueden causar importantes repercusiones, mientras que *Cenchrus longispinus*, *Eragrostis curvula*, *Panicum repens*, *Paspalum urvillei*, *Cortaderia jubata* y *Phyllostachys reticulata* pueden causar repercusiones importantes en las especies autóctonas. La competencia, la transmisión de enfermedades y el impacto en la estructura de los ecosistemas representaron más del 49 % de los mecanismos que provocan impactos ambientales. La prueba exacta de Fisher indicó una asociación significativa entre la puntuación EICAT-IUCN y el ciclo de vida. De las 23 gramíneas que invaden los cultivos, el 60 % ha infestado los arrozales; y *P. repens*, *P. distichum*, *Paspalum dilatatum* y *Leptochloa chinensis* tienen el mayor impacto potencial en las pérdidas de rendimiento (>60 % en algunos casos). *P. distichum* y *P. repens* pueden tener los mayores impactos potenciales tanto en el medio ambiente como en la agricultura. Es necesario establecer prioridades de conservación para abordar los posibles impactos ambientales causados por las especies de gramíneas invasoras en Irán.

Palabras clave: zona ecológica; EICAT-IUCN; riesgo de invasión; gramíneas naturalizadas; mecanismos de impacto; competencia entre plantas.

Introduction

Alien plants can have detrimental impacts on biodiversity, including the decline and local extinction of indigenous species (Vilà et al. 2010; Pyšek et al. 2012a; Pérez et al. 2022). Assessing their potential impacts is important to decision making and the application of successful management strategies (van Kleunen et al. 2018; Pyšek et al. 2020). The Poaceae family constitutes a high portion of the alien flora, for example in Japan (372 out of 1553), China (205 out of 14710), the Czech Republic (152 out of 1378), Italy (163 out of 1200), Belgium (118 out of 2500) (Pyšek et al. 2012b; Galasso et al. 2018; Lin and Ma 2022; Verloove

2023) and Iran (34 out of 311) (Sohrabi et al. 2023b). Generally, grasses possess traits that facilitate long-distance dispersal, establishment, colonization, and transformation of novel environments, and resilience to disturbance and drought (Linder et al. 2017; Bastida et al. 2021; Leal et al. 2022). Alien grasses with high seed production, long seed viability, fast seed germination, vegetative reproduction and low palatability have high potential to invade disturbed sites (Medeiros and Focht 2007). They have spread over large areas of natural ecosystems displacing native species owing to their aggressiveness and highly competitive ability (Damasceno and Fidelis 2020). Furthermore, alien grasses are an important threat to biodiversity conservation due to their resilience to global warming (some are C4 species) and potential for increasing fire risk (D'Antonio and Vitousek 1992).

One way to quantify the potential environmental impacts of alien plants is a standard approach for ranking alien species based on the damage they may cause in recipient areas (Nentwig et al. 2016; Blackburn et al. 2014; Vilà et al. 2019; Kumschick et al. 2020). The IUCN Environmental Impact Classification of Alien Taxa (EICAT-IUCN) is a scheme for classifying alien taxa in terms of the magnitude of their environmental impacts and the mechanism involved to prevent or limit their negative consequences (www.iucn.org). EICAT-IUCN proposes a global assessment where the category assigned to a species is based on the highest impact ever recorded or its highest current impact, observed anywhere (IUCN 2020a and b; Kumschick et al. 2024).

Grasses have also large economic impacts on agricultural lands (Milton 2004; Goggin et al. 2012; Follak and Essl 2012). For example, the rigid ryegrass (*Lolium rigidum*) infestation in southeastern Australia costs an estimated \$93 million (AUD) per annum in grain loss and considerably more in control costs (Bajwa et al. 2021). Johnson grass (*Sorghum halepense*) is classified as an important weed in over 53 countries occurring in 30 different crops (Follak and Essl 2012; Peerzada et al. 2017), causing substantial crop yield loss (Klein and Smith 2021). There are 311 alien plants in Iran and the number is increasing every year (Sohrabi et al. 2023b; Sohrabi and Pagad 2024). A large proportion of alien plants in Iran are grasses (Sohrabi et al. 2023b), but information on their potential impact on both native species and crops is lacking. For example, *Rottboellia cochinchinensis* is present in the Khozestan province, (Dinarvand and Ale-Bakhit 2013; Sohrabi et al. 2023a). This species is known worldwide for invading crops and disturbed habitats in tropical and subtropical regions (Funez et al. 2016). However, we do not know its potential impact in Iran and how it compares to that of other alien grasses present in the country. Overall, there is a lack on the impact of grass invasions in Iran. To contribute to filling this knowledge gap, the aim of this paper is to categorize alien grasses in Iran based on their environmental impacts by using the EICAT-IUCN classification, and furthermore, to assess potential impacts on agricultural production. We assumed that the life cycle, photosynthetic pathway, invasion status and distribution of the grass species in Iran's ecological zones contribute to the severity of the impacts. We also discuss management options for alien grasses for both natural ecosystems and arable lands.

Methods

The selection of plants

Thirty-four alien grasses present in Iran were classified as casual, naturalized, and invasive based on their stage in the invasion process (Richardson et al. 2000; Sohrabi et al. 2023b). The potential environmental impacts of these species were assessed following the EICAT-IUCN guidelines, which consider 12 mechanisms of impact (IUCN 2020b; Volery et al. 2020). The severity of the impacts was categorized as minimal concern (MC), minor (MN), moderate (MO), major (MR), or massive (MV).

We obtained information on the environmental and agricultural impacts of the study of alien grasses from primary scientific literature related to their global alien range. Data on their distribution in Iran, habitat type, introduction pathways, and photosynthetic pathways were sourced from scientific journal articles, reports, books, book chapters (see references in Appendix), and online databases such as WIKTROP (Weed Identification and Knowledge in the Tropical and Mediterranean areas). The distribution of all alien grasses in Iran was assigned to one of the four ecological zones of the country (Fig. 1): (a) Hyrcanian zone: located in the north, with a temperate climate, it extends along the southern coast of the Caspian Sea and the northern part of the country; (b) Khali-j-o-Omani zone: located in the south, covering an area of 2 130 000 ha, it is characterized by a sub-equatorial climate (Heshmati 2012); (c) Zagross zone: situated in the west, this mountainous region covers approximately 4 749 000 ha, characterized by a semi-arid climate and temperate winters; and (d) Iran-o-Touranian zone: dominated by the central Iranian plateau, this zone covers 1 648 000 km² and features a wide variety of climates, surrounded by mountain ranges.

Statistical analysis

A contingency table was used to analyze associations between EICAT-IUCN impact scores (harmful (MV, MR and Mo) and non-harmful (MN, MC and DD)) and variables such as species status (casual and naturalized invasive), life cycle (annual and perennial), and photosynthetic pathway (C3 and C4). Fisher's exact test was applied to identify significant relationships at 0.05 level. Statistical analyses were performed using R 4.3.0 (R Core Team 2022), and the packages ggplot2 (Wickham 2016) and ggpubr (Kassambara 2025) were used for data visualization.

Results

General characteristics of alien grasses

In Iran, there are 22 naturalized, 11 casuals, and one invasive alien grass species. Most of these grasses utilize the C4 photosynthetic pathway (27 species). The C4 pathway is strongly associated with successful naturalization in new areas. Among the 22 naturalized grasses, only Five species utilize the C3 pathway. By longevity, there is a similar number of perennial species

(18) and annual species (17). Notably, only two of the 17 annual species use the C3 photosynthetic pathway. The Poaceae family, due to their seed size, is easily transported through different introduction pathways (Table 1). Approximately 19 species originate from tropical and temperate Asia, while seven are native to Africa and North America, respectively. In Iran, contamination (e.g. seed contamination) was identified as the primary pathway (56%) for the introduction of alien grasses. In most cases, the introduction in Iran has been accidental (14%), with a few exceptions involving deliberate releases, such as *Bambusa vulgaris* and *Chrysopogon zizanioides*.

Impact assessment based on EICAT-IUCN

Based on EICAT-IUCN framework, the most common impact scores for alien grasses in Iran were Minor (MN) and Major (MR); with 13 and seven species assigned to these categories, respectively. Seven species were classified as Data Deficient (DD). Among the 22 naturalized species, ten were rated MN, while five were categorized as MR (Table 1; Fig. 2). We identified the species *Rottboellia cochinchinensis*, *Paspalum distichum*, and *Microstegium vimineum*, as having Massive (MV) impacts. Of these, only *R. cochinchinensis* is invasive in Iran, while the others are naturalized. Additionally, *Cortaderia jubata* and *Phyllostachys reticulata*, which are casual grasses, exhibited major impacts (Fig. 2). Competition (23.5%) and transmission of disease (20%) were the most frequently reported mechanisms of impact for alien grasses. Structural impacts on the ecosystems, hybridization, and toxicity/poisoning were also common (Table 1). Fisher's exact test revealed that there is no evidence of an association between EICAT-IUCN scores and invasive status (p -value: 1, odds ratio=1.03), while the association between EICAT-IUCN scores and life cycle is considered to be statistically significant (p -value= 0.032, odds ratio=0.036). Various EICAT-IUCN scores had shown insufficient evidence to reject the null hypothesis and that there is no evidence of an association with photosynthetic pathways (p -value = 0.74, odds ratio=0.65), although all three grasses with MV score were C4 species.

Distribution of alien grasses in Iran

The proportions of alien grasses in Iran's ecological zones were 61.7% in the Hircanian, 41.1% in the Zagros, 26.4% in the Iran-o-Turanian, and 8.8% in the Kh-O-Omanian zone. The Hircanian ecological zone had the highest proportion of grasses with MN (47.6%) and MR (28.5%) impact scores. In contrast, 50% of the grasses in the Zagros zone had a Minor (MN) impact score, whereas no grasses with this score were recorded in the Kh-O-Omanian zone. The proportion of grasses classified as Data Deficient (DD) was higher in the Iran-o-Turanian zone than in others ecological zones (Fig. 1).

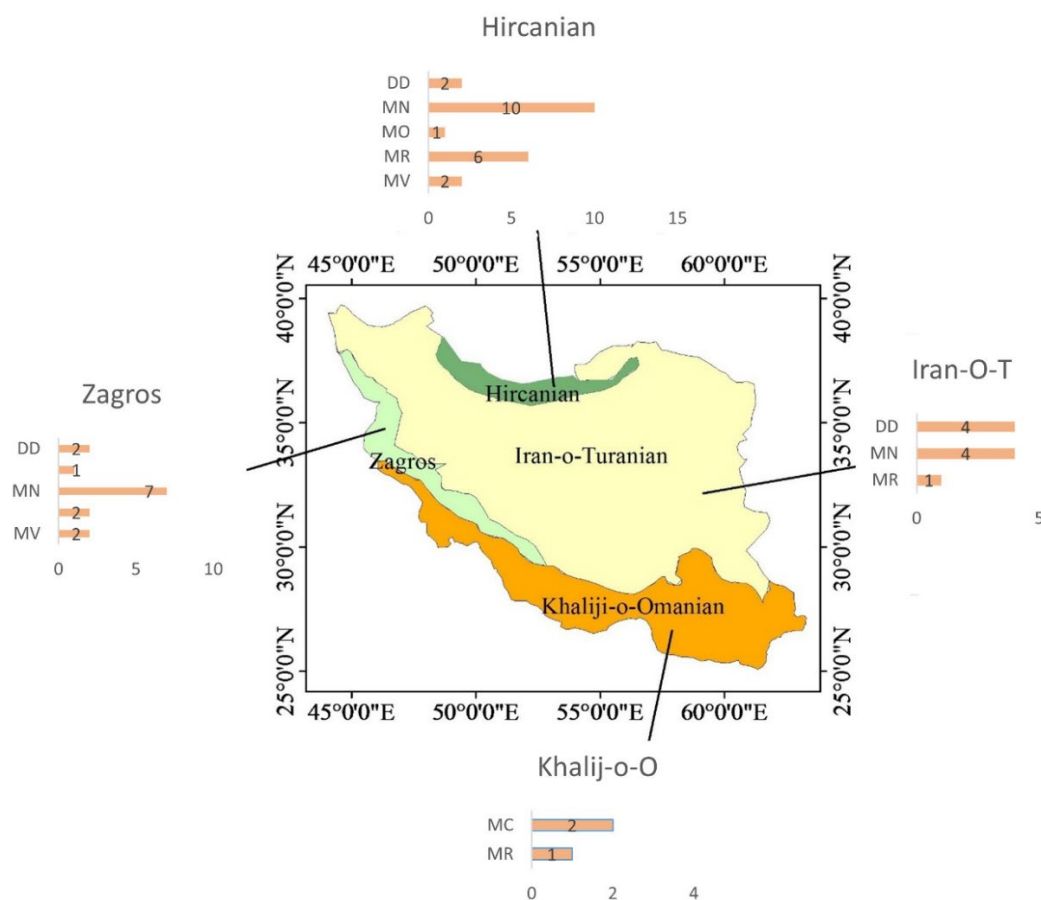


Figure 1. The distribution of 34 alien grasses in Iran along with their EICAT-IUCN scores. The graphs display the number of species classified under each EICAT category (DD - Data deficient, MC - Minimal concern, MN - Minor, MO - Moderate, MR - Major and MV - Massive).

Figura 1. Distribución de 34 gramíneas invasoras en Irán junto con sus puntuaciones EICAT-UICN. Los gráficos muestran el número de especies clasificadas en cada categoría EICAT (DD: datos insuficientes; MC: preocupación mínima; MN: menor; MO: moderada; MR: mayor y MV: masiva).

Table 1. List of 34 alien grass in Iran and their main characteristics and environmental impacts.**Tabla 1.** Lista de 34 especies de gramíneas invasoras en Irán y sus principales características e impactos ambientales.

Plant name	Invasive status	Life cycle	Photosynthesis pathway	Origin	EICAT-IUCN mechanism (score)*	Pathway
<i>Bambusa vulgaris</i> Schrad. ex J.C.Wendl.	Naturalized	Perennial	C3	Tropical Asia, Africa	Competition (MR)	Escape and Release
<i>Bromus catharticus</i> Vahl	Naturalized	Annual	C3	Central America, South America	Competition (MN)	Contaminant
<i>Calamagrostis decora</i> Hook.f.	Naturalized	Perennial	C4/CAM	Temperate Asia	Transmission of diseases (DD)	Escape and Release
<i>Cenchrus longispinus</i> (Hack.) Fernald	Naturalized	Annual	C4	North America, Central America, South America	Competition (MR)	Contaminant
<i>Chloris virgata</i> Sw.	Naturalized	Annual	C4	North America	Transmission of diseases (MC)	Contaminant
<i>Chrysopogon zizanioides</i> (L.) Roberty	Casual	Perennial	C4	Tropical Asia	Structural impact on ecosystem (MO)	Escape and Release
<i>Coix lacryma-jobi</i> L.	Naturalized	Perennial	C4	Tropical Asia	Biofouling (MN)	Contaminant
<i>Cortaderia jubata</i> (Lemoine) Stapf	Casual	Perennial	C3 PACMAD	South America	Structural impact on ecosystem (MR)	Escape
<i>Cynodon transvaalensis</i> Burtt Davy	Naturalized	Perennial	C4	Africa	Transmission of diseases (DD)	Contaminant
<i>Digitaria longiflora</i> (Retz.) Pers.	Naturalized	Annual	C4	Africa, Tropical Asia	Transmission of diseases (DD)	Contaminant
<i>Digitaria stricta</i> Roth	Casual	Annual	C4	Tropical Asia	Transmission of diseases (DD)	Stowaway
<i>Dinebra retroflexa</i> (Vahl) Panz.	Naturalized	Annual	C4	Africa	Transmission of diseases (MN)	Contaminant and Stowaway
<i>Diplachne fusca</i> subsp. <i>uninervia</i> (J.Presl) P.M.Peterson & N.Snow	Casual	Annual	C4	South America, Central America	Competition (DD)	Contaminant
<i>Echinochloa oryzoides</i> (Ard.) Fritsch	Naturalized	Annual	C4	Tropical Asia	Poisoning/toxicity (MN)	Contaminant
<i>Eragrostis curvula</i> (Schrad.) Nees	Naturalized	Perennial	C4	Africa	Structural impact on ecosystem (MR)	Stowaway
<i>Leersia oryzoides</i> (L.) Sw.	Naturalized	Perennial	C3	Europe, Temperate Asia, North America	Chemical Impact on ecosystem (DD)	Contaminant
<i>Leptochloa chinensis</i> (L.) Nees	Naturalized	Annual	C4	Africa, Tropical Asia	Poisoning/toxicity (MN)	Contaminant
<i>Microstegium vimineum</i> (Trin.) A.Camus	Naturalized	Annual	C4	Temperate Asia	Competition (MV)	Stowaway
<i>Oryza rufipogon</i> Griff.	Naturalized	Annual	C4	Tropical Asia, Australasia	Hybridization (MN)	Contaminant and Stowaway
<i>Oryza sativa</i> L.	Casual	Annual	C4	Tropical Asia	Hybridization (MN)	Escape
<i>Panicum capillare</i> L.	Casual	Annual	C4	North America	Transmission of diseases (DD)	Contaminant
<i>Panicum repens</i> L.	Naturalized	Perennial	C4	Africa, Europe, Tropical Asia	Competition (MR)	Contaminant
<i>Paspalum dilatatum</i> Poir.	Naturalized	Perennial	C4	South America	Poisoning/toxicity (MN)	Contaminant
<i>Paspalum distichum</i> L.	Naturalized	Perennial	C4	North America, Central America, South America	Biofouling (MV)	Contaminant
<i>Paspalum urvillei</i> Steud.	Casual	Perennial	C4	South America	Structural Impact on ecosystem (MR)	Stowaway
<i>Phyllostachys reticulata</i> (Rupr.) K.Koch	Casual	Perennial	C3	Temperate Asia	Physical Impact on ecosystem (MR)	Escape
<i>Rottboellia cochinchinensis</i> (Lour.) Clayton	Invasive	Annual	C4	Africa, Tropical Asia	Structural Impact on ecosystem (MV)	Contaminant
<i>Saccharum spontaneum</i> L.	Casual	Perennial	C4	Tropical Asia, Africa, Australasia	Competition (MN)	Escape and Release

Continued Table 1. / Continuación Tabla 1.

Plant name	Invasive status	Life cycle	Photosynthesis pathway	Origin	EICAT-IUCN mechanism (score)*	Pathway
<i>Setaria italica</i> (L.) P.Beauv.	Naturalized	Annual	C4	Temperate Asia	Poisoning/toxicity (MN)	Contaminant
<i>Setaria parviflora</i> (Poir.) Kerguélen	Naturalized	Annual	C4	North America, Central America, South America	Poisoning/toxicity (MN)	Contaminant
<i>Sorghum bicolor</i> (L.) Moench	Casual	Perennial	C4	Africa	Poisoning/toxicity (MN)	Escape
<i>Sporobolus virginicus</i> (L.) Kunth	Naturalized	Perennial	C4	Africa, Tropical Asia, Australasia, Pacific Islands, Central America, North America, South America	Competition (MC)	Stowaway
<i>Triticum turgidum</i> subsp. <i>durum</i> (Desf.) Husn.	Naturalized	Annual	C3	Africa	Hybridization (MN)	Release
<i>Zoysia matrella</i> (L.) Merr.	Casual	Perennial	C4	Tropical Asia, Pacific Islands	Hybridization (MC)	Escape

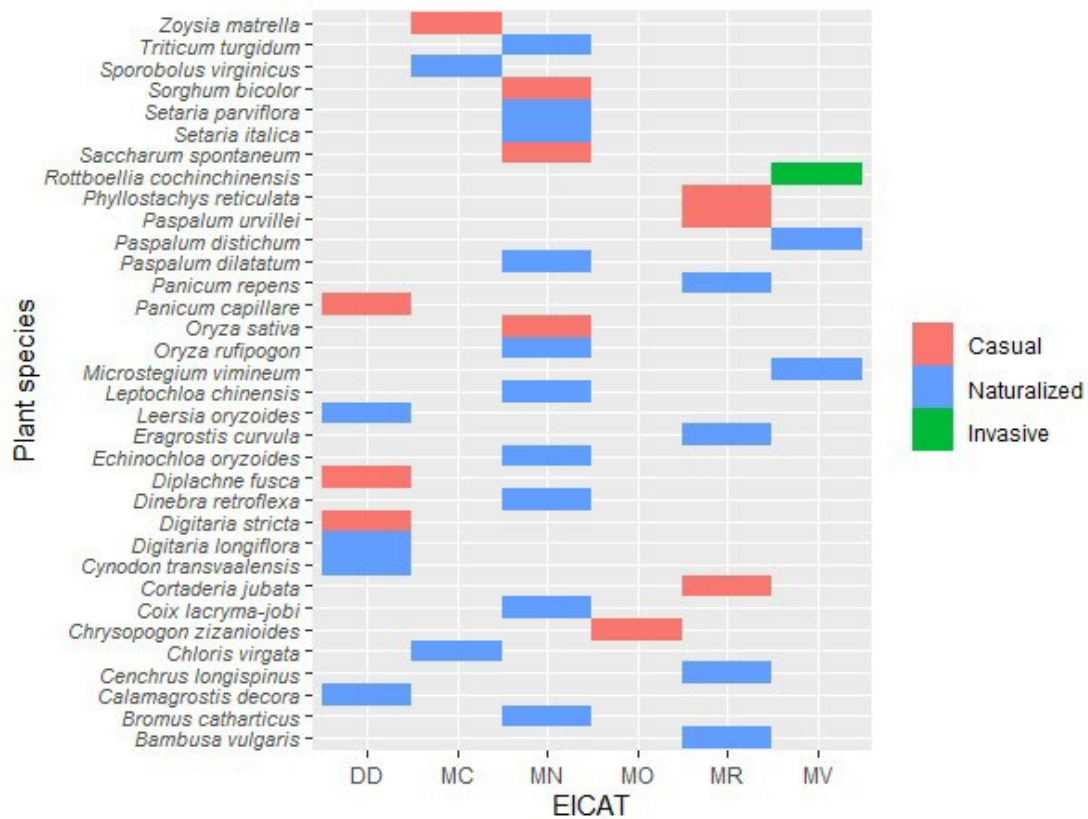


Figure 2. Invasion status and EICAT-IUCN impact score of 34 alien grasses in Iran. EICAT-IUCN ranking included data deficiency (DD), minimal (MC), minor (MN), moderate (MO), major (MR) or massive (MV) impact. Two cases are subspecies: *Triticum turgidum* subsp. *durum* and *Diplachne fusca* subsp. *Uninervia*.

Figura 2. Estado de invasión y puntuación de impacto EICAT-UICN de 34 gramíneas invasoras en Irán. La clasificación EICAT-UICN incluyó datos insuficientes (DD), impacto mínimo (MC), menor (MN), moderado (MO), mayor (MR) o masivo (MV). Dos casos son subespecies: *Triticum turgidum* subsp. *durum* y *Diplachne fusca* subsp. *Uninervia*.

Impact of alien grasses on agricultural areas

Twenty-three of the 34 alien grass species identified in Iran are invading agricultural areas (Table 2). The majority of these species were observed in rice fields, comprising 14 species. Six species were observed in maize and sugarcane fields, while only five species were recorded in orchards and vineyards. The primary mechanisms of impact include competition with crops and serving as hosts for pests. Furthermore, some species exhibited herbicide resistance, allelopathic potential, and toxicity to animals (Table 2). We recorded thirteen alien weedy grass species in northern Iran, six in the southern region, with the remaining species distributed across central and eastern Iran (Table 2).

Table 2. Alien weedy grasses in Iran invading agricultural areas and their characteristics. See full Literature in [Appendix](#).**Tabla 2.** Las gramíneas invasoras de zonas agrícolas en Irán y sus características. Véase la bibliografía completa en el [Apéndice](#).

Alien plant (Family)	Infected crops and habitats	Impact mechanism	% field infestation or yield reduction	Recorded countries as weed and alien	Management	Distribution in Iran	References
<i>Bromus catharticus</i> (Poaceae)	Alfalfa, wheat and barley fields (winter crops)	Competition, herbicide resistance, host for pathogens, contaminant of wool, fire hazard	20% in winter crops	In more than 16 countries	Prevent seed set for 1-2 years. Chemical: In degraded areas use 10 ml/10 L glyphosate on seedlings, young plants or when flowering.	Khorramabad	Kloppers & Pretorius 1993; Alucinio & Arturi 2002; Dastgheib et al. 2003; Poggio et al. 2004; Hamzeh'ee et al. 2007; Yannicari et al. 2021
<i>Cenchrus longispinus</i> (Poaceae)	Cereals, legume crops, vineyards, pastures	Competition, contamination of wool, dried fruit and lucerne hay, fire hazard	No data	18 crops in 35 countries	Chemical: Glyphosate 360 g/L, MSMA 720 g/L minimize tillage	Babolsar, Mazandaran	Anderson 1997; Szigetvári 2002; Naqinezhad 2012; Soltani et al. 2009; Verloove & Gullon 2012; Strat et al. 2017
<i>Chloris virgata</i> (Poaceae)	Mungbean, alfalfa, corn	Competition, herbicide resistance	Caused a total grain loss of 0.4 mt annually, resulting in a revenue loss of AUD 7.7 million. In mungbean, about 50 <i>C. virgata</i> plants m ⁻² caused a yield loss of greater than 70%	In more than 70 countries	Chemical: Atrazine and glyphosate	Zabol, Balouchestan	Termeh 2000; Llewellyn et al. 2026; Rachaputi et al. 2019; Manali et al. 2020; Mahajan & Chauhan 2021
<i>Cortaderia jubata</i> (Poaceae)	Environmental weed, cereal and rice	Competition	No data	In more than 5 countries	Chemical and Mechanical Methods	North of Iran	Lambrinos 2000; Stanton & DiTomaso 2004; Drewitz & DiTomaso 2004; EPPO 2019
<i>Digitaria longiflora</i> (Poaceae)	Rice, corn, sugarcane	Competition, herbicide resistance host for pathogens	At its highest density it reduces yields by as much as 62%	In more than 15 countries	Integrated weed control systems*	Fars, Khuzestan	Galinato et al. 1999; Lapierre & Signoret 2004
<i>Dinebra retroflexa</i> (Poaceae)	Corn, cotton, sugar cane, rice	Competition, host for pathogens	No data	In more than 12 countries		Khuzestan	Mozaffarian, 1994; Lapierre & Signoret 2004; Tanji 2020
<i>Diplachne fusca</i> subsp. <i>uninervia</i> (Poaceae)	On the edges of irrigation channels	Competition	It reduces yields by as much as 40%	In more than 12 countries	Chemical	Khuzestan	McIntyre et al. 1989; Saito 2010; Ghanbarpour et al. 2015; Ebrahmi et al. 2017; Süveges et al. 2021; McIntyre et al. 2023
<i>Echinochloa oryzoides</i> (Poaceae)	rice	Competition, herbicide resistance	Dense infestations of <i>E. oryzoides</i> can cause more than 50% <i>O. sativa</i> yield loss if not controlled	In more than 190 countries	Integrated weed control systems*	Gilan	Hill et al. 1994; Fischer, 2000; Avarseji 2015; Haghnama 2020; Zand et al. 2019; Pouramir & Yaghoubi 2021
<i>Eragrostis curvula</i> (Poaceae)	Vineyards, horticultural crops and orchards	Competition, grazing, fire hazard		In more than 50 countries	Graze heavily while young and succulent	Khorasan	Johnston et al. 2005; Firn 2009; Firn et al. 2013, 2017; Godfree et al. 2017; Brown et al. 2023
<i>Leersia oryzoides</i> (Poaceae)	Rice fields	Competition, blocking canals and ditches, water quality and nutrients cycling	The reduction of yields various between 15 -20%	In 4 countries	Integrated weed control systems*	Gilan Bandar-e Anzatl	https://www.ikisan.com Mozaffarian 1991; Deaver et al. 2005; Pierce et al. 2007, 2009; Koontz & Pezeshki 2011
<i>Leptochloa chinensis</i> (Poaceae)	Rice	Competition, host for pathogens	6-68% upon to weed density	In 5 country	Integrated weed control systems*	Khuzestan	Pane et al. 1996; Peng et al. 2020; Dong et al. 2020; IRRI. 2023; Hayyat et al. 2023
<i>Microstegium vimineum</i> (Poaceae)	The borders of ditches, forests	Competition, host for pathogens	No data	In more than 10 countries	Can be removed by hand-weeding, mowing, or by Chemicals: selective herbicides	Mazandaran, Golestan, Gilan	Bor 1970; Hamzeh'ee & Naqinezhad 2009; Johnson et al. 2015; Zhao & Brenner 2021

Continued Table 2. / Continuación Tabla 2.

Alien plant (Family)	Infected crops and habitats	Impact mechanism	% field infestation or yield reduction	Recorded countries as weed and alien	Management	Distribution in Iran	References
<i>Oryza sativa f. spontanea</i> Roshev. (Poaceae)	Different rice cropping systems	Competition	At its highest density it reduces yields by as much as 50-60%	In more than 17 countries	Integrated weed control systems*	Gilan	Cao et al. 2007; Galvin et al. 2020; Takasi et al. 2021
<i>Oryza rufipogon</i> Griff. (Poaceae)	Different rice cropping systems	Competition, hybridization	No data			Gilan	Gupta & Upadhyay 2000; Jamjod et al. 2005; Na Chiangmai & Phakatip 2011; Amarasinghe et al. 2020
<i>Panicum capillare</i> (Poaceae)	Corn, soybeans, sorghum, and wheat	Competition, poisoning/toxicity, host for pathogens	4-5% yield loss in corn and soybean at a weed density of 5 plants/m ²	In more than 37 countries	Chemical Translocated herbicides	Ghazvin	Kingsbury 1964; Rermeh 2000; Clements et al. 2004; Quinn et al. 2014; Ontario Weed Committee 2021
<i>Panicum repens</i> (Poaceae)	Perennial crops and rice	Competition, allelopathy, host for pathogens	at its highest density and without control it reduces yields by as much as 80%	In more than 12 countries	Deep tillage+ burnings in combination with herbicide applications Chemical: Quinclorac diclofop-methyl	Khuzestan, Golestan	Chandrasena & Peiris 1989; Hossain 1996; Hossain et al. 1999; Stephenson et al. 2006; Akamine et al. 2007
<i>Paspalum dilatatum</i> (Poaceae)	Rice	Competition, poisoning/toxicity, seed contaminants, blocking channels	30-50% rice reduction upon the density of weed	In more than 68 countries	Chemical: trifloxysulfuron, DSMA, MSMA, quinclorac	Mazandaran, Gilan, Tehran	Jacobo et al. 2009; Ala et al. 2014; Tejera et al. 2016; Napier et al. 2016; Nasser 2016; Golmohammadi et al. 2019; Faghhi et al. 2020; Bondy et al. 2023;
<i>Paspalum distichum</i> (Poaceae)	Pulses, maize, rice, root crops, and vegetable crops.	Competition, blocking channels, loss fish population	at its highest density it reduces yields by as much as 75-80%	In more than 57 countries	Can be controlled by 2 or 3 harrowings during land preparation for transplanted rice. Chemical: Glyphosate and butachlor reported to be effective.	Gilan, Mazandaran	Kumar & Mittal 1993; Bernez et al. 2005; Kojima et al. 2005; Le et al. 2005; Phuong et al. 2005; Stroh 2006; Faghhi et al. 2020; Ladmakhi-nezhad et al. 2023
<i>Paspalum urvillei</i> (Poaceae)	sugarcane	Competition, host for pathogens, allelopathy	No data	In more than 30 countries	Slashing followed by Chemical treatment	Karaj	Jeffries et al. 2017; Ghorbani et al. 2021
<i>Rottboellia cochinchinensis</i> (Poaceae)	Soybean, corn, cotton, peanut, rice, and sugarcane	Competition, host for pathogens, allelopathy	20-70%	In more than 25 countries	IPM programs / Chemical: pre-emergence herbicide)	Khuzestan	Millholon 1992; Meksawat & Pornprom 2010; Bolfrey-Arku et al. 2011; Correia 2016
<i>Saccharum spontaneum</i> (Poaceae)	Tea, sugarcane, cotton and sorghum	Competition, host for pathogens, allelopathy, nutrients cycling	66%	In more than 8 countries	Tillage+ Chemical (pre-emergence herbicide)	Mazandaran	Waterhouse 1994; Holm et al. 1997; Bonnett et al. 2014
<i>Setaria italica</i> (Poaceae)	Border of crop field	Competition, poisoning/toxicity, host for pathogens, hybridization	No data	In more than 100 countries	Chemical: (EPTC)	Birjand, Kerman, Yazd, and Isfahan, Mazandaran, Khorasan	Dawson 1978; Darmency et al. 1978; Dekker 2003; Abbaspoor et al. 2020
<i>Setaria parviflora</i> (Poaceae)	Pasture and cereals, alfalfa, sod, lawn seed, rice and vineyards	Competition	at its highest density it reduces yields by as much as 40%	In more than 43 countries	Using a strimmer in the spring to remove seed heads before they are viable can suppress its reproductive potential	Mazandaran	Doust & Kellogg 2002; Austin 2006; Dyer et al. 2022

*Management in rice: Integrated weed control systems, involving the use of certified seed (or good quality weed-free seed), good land preparation, the use of stale seedbeds to encourage weed germination before seeding, careful crop and water management, herbicides and crop rotation are needed. In crop rotation, rice may be rotated with other crops in alternate seasons and an appropriate herbicide can be used to destroy weedy rice seedlings in these crops.

Discussion

General characteristics of alien grasses

Alien grasses contribute 13%, 9%, and 7.6% to the total number of naturalized, casual, and invasive alien plants in Iran, respectively (Sohrabi et al. 2023b). The proportion of naturalized grasses in Iran is comparable to findings from other studies in China (Lin and Ma 2022) and worldwide (Perterra et al. 2023). The faster growth rates and larger sizes of C4 species enhance their establishment success compared to C3 species (Jia et al. 2016). *Spartina alterniflora* invasion, a perennial C4 grass in China, has been linked to its rapid growth and ability to stabilize tidal flats (Cheng et al. 2006). The worse invasive alien grasses have C4 photosynthetic pathway (GISD 2013). For example, *Cenchrus spinifex* is one of the foremost invasive C4 grass in Hungary (Botta-Dukát and Balogh 2008). Numerous studies have highlighted the successful establishments of the perennial grasses from temperate-tropical regions due to their higher competitive ability in warm climates (Hacker and Dethier 2006; Lopes et al. 2023). In our study, most C3 grasses were perennial. The rapid spread of these species, whether by seed or vegetative propagation; facilitates their invasion into disturbed areas, such as the Cerrado in Brazil (Zenni et al. 2020). In addition, Seed contamination as the primary pathway of new introduction is consistent with findings in Europe (Poschlod et al. 2009).

Impact assessment based on EICAT-IUCN

Among different mechanisms competition is well documented, while other mechanisms, such as hybridization and biofouling, are more challenging to assess due to indirect evidence and complex data interpretation (Foxcroft et al. 2019). For example, detecting hybridization impacts requires molecular research, which is costly and more time-consuming compared to evaluating allelopathy or competition (Gioria and Osborne 2014; Kalisz et al. 2021). Phenolic acids are the main identified allelochemicals (67%) in the Poaceae family (Favaretto et al. 2018). In addition to irritating trichomes on the leaf sheaths of *R. cochinchinensis*, its phytotoxic effects on adjacent plants specie cause reduced growth of seedlings (Meksawat and Pornprom 2010). Changes in disturbance regimes and natural succession have been reported for grasses like *Chrysopogon zizanioides*, due to their root system in upper horizons of the soil (Eab et al. 2015; Freschet and Roumet 2017; Badhon et al. 2021). The transmission of disease is another significant mechanism, and the importance of grasses species in transmitting endophytic fungi is well known (Lapierre and Signoret 2004; Yuan et al. 2010). For example, *Bipolaris gigantea*, a foliar fungal pathogen in alien *Microstegium* populations, had significant impact on biomass responses of three native North American grass species (Kendig et al. 2021); and *Xylella fastidiosa*, a widespread bacterial pathogen of olives, almond and citrus, can be transmitted indirectly (xylem-feeding insects) by alien grasses (Najberek et al. 2022).

Distribution of alien grasses in Iran

The highest number of naturalized and invasive plants in the Hircanian ecological zone is attributed to its favorable environmental conditions and high population density (Sohrabi et al. 2023a). Biodiversity hotspots with high environmental and economic value are at the greatest risk of biological invasions and should therefore be prioritized for invasive species management (Li et al. 2016; Yang et al. 2023). The Caspian forests, located in the Hircanian zone and recognized as a UNESCO World National Heritage site (UNESCO 2019), are a critical area in Iran that requires attention as a potential hotspot for biological invasion. *Rottboellia cochinchinensis* was found in the Zagros zone and it is the only invasive grass species recorded in Iran. With a high seed production potential of over 3000 seeds per plant, immediate action is essential to curb its rapid spread (Dinarvand and Ale-Bakhit 2013). Understanding the ecological zones most vulnerable to invasion is crucial for predicting the threats posed by alien plant invasions (Sohrabi and Gharekhloo 2015). Effective management strategies can be better formulated and implemented by combining distribution data with environmental impact scores (Panda et al. 2017; Sohrabi et al. 2023a). The agricultural lands and ruderal areas are frequently cited as the primary habitats invaded by alien plants (Gaertner et al. 2017; Sohrabi et al. 2023b; Potgieter et al. 2024). However, it is worth highlighting that many cultivated alien grasses have significantly contributed to agricultural production and economic development (Randriamampianina et al. 2024). For instance, *Sorghum bicolor* and *Cortaderia jubata* have been introduced to Iran as crops and ornamental plants, respectively. Globally, *Echinochloa oryzoides* and *Setaria italica* are among the most commonly encountered weedy grass species. Their frequent occurrence can be attributed to their remarkable adaptability to various environmental stressors, such as flooding, drought, and salinity (Mohammadvand et al. 2012; Lapuimakuni et al. 2018; Kaya-Altup et al. 2019; Nisa and Jadid 2021). Among the most damaging species in agricultural areas are *P. repens*, *P. distichum* and *L. chinensis*, which pose a significant threat to crop production, potentially causing yield losses of up to 60% (Hossain et al. 2001; Kojima et al. 2005; Hayyat et al. 2023). *Paspalum distichum* infestation has been reported in perennial crops throughout Spain, where it threatens olive and vineyard production (Costa 1997). The introduction of *P. distichum* for pasture purposes has increased its potential to invade, particularly arid regions, and its impact extends to river flora and the integrity of river systems in Portuguese floodplains (Bernez et al. 2005; Driscoll et al. 2014). Similarly, the negative impact of *P. repens* has been extensively documented in agricultural areas and native plant communities in the USA, where its management in flood control systems for Florida's citrus groves alone costs \$2 million annually (Cuda et al. 2007; Langeland and Burks 2022). *Leptochloa chinensis* is a serious weed in the direct-seeded rice crop, causing substantial yield reductions at high densities due to its competitive ability, which is attributed to its C4 photosynthesis pathway and increased biomass production rate (Benvenuti et al. 2003; Sage et al. 2012; Deng et al. 2021). In total, there are 25 predominant weedy grass species found across various agricultural lands in Iran, of which seven species, accounting for 28%, are alien (Mozafarian 2021; Sohrabi et al. 2023b, 2024). Therefore, a better understanding of the portion of alien grasses in the weed flora and their impact can benefit and improve the ecological sustainability of crop production systems.

Management of alien grasses

Certain interventions can reduce the propagule pressure and the likelihood of establishment and spread of newly introduced alien grasses (Perrings et al. 2005; Simberloff 2009; Siddiqui et al. 2022). Strategies such as limiting contamination vectors, monitoring pathways for target grasses, controlling contaminants, and adopting long-term approaches have been suggested as the most effective methods for managing invasive grasses in specific areas (Pyšek et al. 2011; Gentili et al. 2021; Rudell et al. 2023). However, we highlight that the most accurate management options will depend on the infested habitat (natural areas or agricultural lands) and the life cycle of the species (annual or perennial). In natural areas, the most effective control methods often involve an integrated approach that include burning, mowing, hand clearing, and herbicides application (Marushia and Allen 2011). In agricultural areas, effective control typically involves the use of certified seeds, proper land preparation, stale seedbeds to promote weed germination prior to seeding, careful crop and water management, herbicides, and crop rotation (Milton 2004; Zand et al. 2017; Khasraw et al. 2023; Gharekhloo et al. 2020; Siddiqui et al. 2022).

The application of herbicides is a widely used strategy for managing invasive plant species, particularly in agricultural systems. However, the continuous and intensive use of these chemicals has resulted in the emergence of herbicide-resistant weed populations, posing significant challenges to crop productivity and sustainability (Hassanpour-bourkheili et al. 2024; Heap 2024). To achieve complete control of *P. repens* in naturally infested fields often requires multiple applications of methyl sulfanilylcarbamate (a dihydropteroate synthase inhibitor), as plowing-induced rhizome fragmentation disperses the weed across various soil layers, complicating eradication (Hossain 2001). In paddy fields in Rasht, Iran, bensulfuron-methyl, an acetolactate synthase inhibitor, has demonstrated higher efficacy in controlling *Echinochloa oryzoides* (Pouramir and Yaghoubi 2020). In USA rice fields, *Leptochloa chinensis* and *P. distichum* have evolved herbicide resistance due to the repeated application of a single herbicide or herbicides group (Chauhan et al. 2012). To manage *P. distichum* and mitigate the risk of glyphosate resistance, the integration of herbicides with different modes of action has been recommended (Alcantara et al. 2016).

As a sustainable alternative to herbicides, biological control methods have been suggested, including the use of grazing animals such as rabbits, goats, sheep, and ducks, as well as cover crops and intercropping. These approaches have been explored for managing invasive species like *Paspalum repens*, *P. distichum*, and *Rottboellia exaltata* in turmeric fields (Prabhakaran Nair 2013).

Relying on a single control tactic may be insufficient for effectively managing invasive plant species, particularly given the high reproductive potential and dispersal ability of certain species. In this context, Integrated Weed Management (IWM) presents a promising strategy for controlling and mitigating the impact of invasive species in both agricultural and natural ecosystems (Gonzalez-Andujar 2023).

Conclusion

This study, based on the EICAT-IUCN assessment, highlights the significant impact potential of several alien grass species in Iran, including *Rottboellia cochinchinensis*, *Paspalum distichum* and *Microstegium vimineum*. These species primarily affect ecosystems through competition, disease transmission, and structural alterations. The prioritization of management efforts should be guided by these findings, particularly for *P. distichum* and *Panicum repens* which pose substantial threats to biodiversity and agricultural productivity. The highest number and impacts of alien grasses in Iran were found in the Hircanian zone, followed by the Iran-o-Turanian zone.

Notably, a correlation between EICAT-IUCN score and life cycle underscores the critical role of perennial and species in driving environmental impact. Given the prevailing warming conditions, it is crucial to focus on the introduction and management of alien C4 perennial grasses in Iran. Effective management of strategies will depend on the life cycle of the species and the nature of the invaded habitat, though the most successful approaches typically involve a combination of methods.

Data Availability

More information is available in [Appendix](#) and raw data will be presented upon reasonable request to the corresponding author.

Financing, required permits, potential conflicts of interest and acknowledgments

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The authors declare that they have no conflicts of interest.

Authors' contribution

SS, JG, JLG-A, MV, designed the study; SS collected the data; SS analyzed the data; SS led the writing of the manuscript, and all authors contributed critically to the drafts and gave final approval for publication.

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Appendix / Anexo

Literature on the environmental and agricultural impacts of alien grasses species in Iran cited on **Table 2**.

Bibliografía sobre los impactos medioambientales y agrícolas de las especies de gramíneas invasoras en Irán citadas en la **Tabla 2**.

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