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RESEARCH ARTICLES

Competition between alien and native species in xerothermic steno-Mediterranean grasslands: *Cenchrus setaceus* and *Hyparrhenia hirta* in Sicily and southern Italy

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Abstract

Perennial dry grassland communities, vital for plant biodiversity conservation in the Mediterranean, often harbor rare and endangered species. However, these habitats face threats, including the invasion of alien species. *Cenchrus setaceus*, a highly invasive grass, is spreading in the Mediterranean region. Historical records and observations document its establishment and invasiveness across various Italian regions. This study investigates the impact of *C. setaceus* on native grasslands dominated by *Hyparrhenia hirta*. We assessed the impact of *C. setaceus* invasion on plant biodiversity in Sicily and southern Italy, and we identified and characterized plant species' composition using Ellenberg indicator values. The intention to analyze species richness, diversity, and ecological indicators is also emphasized. Starting from the use of the phytosociological method, multivariate analysis and Ellenberg indicator values to assess the impact of *C. setaceus* on grasslands composition were considered. There are several similarities and differences in diversity, floristic composition, and ecological traits between the two grassland types. A deep comparison with central European studies and evaluation of the impact of *C. setaceus* on species richness and community dynamics in Mediterranean habitats were concluded. Although *C. setaceus* is invading native grasslands, it does not drastically reduce species richness. The ecological implications of the invasion are explored, urging ongoing monitoring and collaborative efforts for effective conservation. The importance of interdisciplinary cooperation is highlighted to address the threat of invasive species and sustain the biodiversity of Mediterranean grasslands.

Keywords Biological invasions · Mediterranean grasslands · *Pennisetum setaceum* · Plant invasions · Species richness

Introduction

Perennial dry grasslands communities represent important habitats for plant biodiversity conservation in the Mediterranean area (Faber-Langendoen and Josse 2010). Although they represent secondary aspects due to forest degradation processes, are considered the most species-rich plant communities and often contain a large number of rare and endangered native species (San Miguel 2008). These communities are mainly used by man for animal husbandry (Buisson and Dutoit 2006; San Miguel 2008). Although this activity has decreased in many European countries, in the Mediterranean ones it continues to be of great economic importance (Hadjigeorgiou 2011). One of the main threats of these communities are alien invasive species (Simberloff et al. 2013) that can modify biotic and abiotic conditions of habitats making them less suitable for native taxa and causing numerical

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changes and sometimes even extinctions of the less resilient elements (Cronk and Fuller 1995, Walker and Steffen 1997, Lozano et al. 2023, Caruso and Capuano 2023). Increasing temperatures resulting from climate change are expected to enhance the proliferation of alien species within temperate grasslands. Research indicates a direct relationship between rising temperatures and increase and speeds of germination in alien species, a trend that contrasts with the behavior observed in native species (Trotta et al. 2023). In particular, *Cenchrus setaceus* (Forssk.) Morrone (= *Pennisetum setaceum* (Forssk.) Chiov.) (Poaceae) is one of the most invasive and threatening plants of Mediterranean area (Guarino et al. 2021; Lozano et al. 2023). This alien species was introduced in Italy during the last century and its invasive spread has been remarkable in the last twenty years (Pasta et al. 2010). This phenomenon deserves to be monitored and interpreted on the basis of current knowledge on the dynamics and interactions of invasive alien species with native ones. This to evaluate the impact of *C. setaceus* invasion on the habitats also in consideration of any control actions.

Cenchrus setaceus is a C4 perennial, wind-dispersed, grass native to North Africa and western Asia where it grows in arid coastal and desert areas (Maire 1952). This species, cultivated as ornamental, has become invasive in Hawaii and the southern continental United States, Australia, the Canary Islands, southern Europe, and southern Africa (Kaufman 2022). It is listed in the EU Regulation 1143/2014 among the invasive species of European Union concern. In Italy, it occurs in Sardinia, Tuscany, Lazio, Campania, Apulia, Calabria, and Sicily (Celesti-Grapow L. et al. 2009; Buono 2013; Lucchese 2017; Galassso et al. 2018a, 2018b; Laface et al. 2020; Musarella et al. 2020; Stinca et al. 2021). This species grows from the sea level to 450–500 m a.s.l., on disturbed soils, on scree slopes at the base of the cliffs, as well as on rocky habitats (D'Amico and Gianguzzi 2006; Pasta et al. 2010). These areas were actually occupied by perennial grasslands dominated by the native *Hyparrhenia hirta* (L.) Stapf.

Hyparrhenia hirta is a perennial grass with similar traits than *C. setaceus*, it is native to the Mediterranean Region and southern Africa (Maire 1952). This species is expanding, naturally and with the help of man, its range; now includes regions with a subtropical, warm temperate or Mediterranean climate in Europe, Africa, Asia and Oceania (Chejara et al. 2010). The EU Habitats Directive (92/43/EEC) preserves natural habitats such as the one dominated by *Hyparrhenia hirta* (6220*) that is reported as a priority conservation one.

Cenchrus setaceus, along the Tyrrhenian and the Ionian coasts of Sicily and Calabria, is gradually establishing itself at expenses of *H. hirta.* For instance, on rocky substrates outcropping of Monte Pellegrino, near Palermo (Siciliy), has been described the association *Pennisetum setacei-Hyparrhenietum hirtae* by Gianguzzi et al. (1993) that describes an aspect of transition from the grasslands dominated by *H. hirta* to that dominated by *C. setaceus.*

The first information on cultivation of *Cenchrus setaceus* in Sicily dates back to Bruno (1939), who reports having introduced seeds from former Abissinia (approximately current Ethiopia and Eritrea) for experimentation on this species as forage at the Botanical Garden Palermo. The first record of this plant, casual alien in Italy, refers to Frigato (1954) from Liguria. In this region the species has now definitely disappeared (Galasso et al. 2018a). In Sicily *C. setaceus* was recorded as naturalized in 1959 near Palermo, on mount Pellegrino (Pignatti and Pignatti Wikus 1963), and in 1960 near Catania (Borruso and Furnari 1960) wrongly named *Pennisetum villosum* R.Br. (= *Cenchrus longisetus* M.C.Johnst.).

The report from southern peninsular Italy is more recent and the species has immediately shown its invasiveness: in fact, in Calabria (the region of the Italian Peninsula closest to Sicily) Castellano and Marino (2007) reported it as "casual", Musarella et al. (2020) as "naturalized" and Laface et al. (2020) and Spampinato et al. (2022) as "invasive".

Therefore, in agreement with Pasta et al. (2010), C. *setaceus* began to behave like an invasive species in Italy around the beginning of the 80s of the last century, starting from Sicily and still going up today along the Italian peninsula. The species was reported in Apulia (Buono 2013), in Lazio (Lucchese 2017), Tuscany (Galasso et al. 2018b), and Campania (Stinca et al. 2021).

The aims of this contribution are: (A) to evaluate if it is present and the magnitude of response in plant biodiversity loss in Sicily and southern Italy due to the expansion of *Cenchrus setaceus*, and (B) to hence to identify and characterize plant species composition responding to the spread of *C. setaceus* in the *H. hirta* grasslands in Sicily and southern Italy. In addition, we described these species' response-based characteristics employing their Ellenberg indicator values. Ellenberg indicator values are a useful tool to delineate the relationship between plants and environment, recognising to each species a functional role as biological indicator by indicating aspects of habitat quality such as light, temperature, soil moisture, soil pH value and nutrient availability (Ellenberg et al. 2001; Guarino et al. 2012).

Specifically, we assessed (a) the quantitative and qualitative variation of species associated with grasslands dominated by *C. setaceus* compared to those dominated by *H. hirta* and (b) how and which specific Ellenberg indexes vary with the replacement of the dominating grass.

Similar studies have been done in central Europe, where it has been reported that dominance by a species is correlated to a decline in species richness, but reveal that alien dominants do not have a stronger impact than the native ones (Czarniecka-Wiera et al. 2019). We wanted to verify if the same phenomenon is observed in the Mediterranean.

The results of this study will enrich the information available on *C. setaceus* grasslands by providing useful data for their management in terms of safeguarding biodiversity and will provide useful information for the conservation of endemic species present in dry grasslands communities.

Materials and methods

Study area and sampling design

The portal of the Flora of Italy (https://dryades.units.it/floritaly/index.php), the most updated working checklist for this territory, reports *Cenchrus setaceus* as invasive in Sardinia, Calabria and Sicily. We chose to investigate its impact in Sicily and Calabria because, currently, they are the only regions where it forms extensive grasslands. In Sardinia the species does not penetrate the semi-natural vegetation remaining confined along the road axes (G. Brundu pers. comm.). Three localities were chosen where the occurrence of *C. setaceus* is more severe: the surroundings of Palermo (NW Sicily), San Gregorio-Catania (E Sicily), and southern Calabria. In each area 10 sampling plots were chosen: 5 dominated by *C. setaceus* and 5 dominated by *H. hirta* with similar exposition and inclination per pair. Details of each sampling plot are reported in Table 1. We sampled grasslands across from 2019 to 2021. In each sampling area we established a square of 100 m^2 at a place that was as homogeneous as possible in terms of topography and vegetation physiognomy. In each square the presence of individuals of all species of vascular plants was recorded. The percentage cover of each species was visually estimated. Taxa nomenclature follows Bartolucci et al. (2018) and Galasso et al. (2018). Ellenberg indicator values derived from Domina et al. (2018) and Guarino and La Rosa (2019).

The study followed the Braun-Blanquet phytosociological approach (Braun-Blanquet 1964). A total of 30 unpublished phytosociological relevés per 174 taxa were processed. All the relevés were analysed using classification and ordination methods. A multivariate analysis (Linkage method: Ward`s, Distance measure: Euclidean) was applied (Bray et al. 1957; Ward 1963). Cluster analysis and ordination of the dataset were performed using PC-ORD 6 software (McCune and

Table 1 Details of the sampling plots of *Hyparrhenia hirta* (L.) Stapf subsp. *hirta* and *Cenchrus setaceus* (Forssk.) Morrone in Sicily and in Calabria regions (Italy)

Plot name	Cluster	Coordinates (WGS84)		Locality	Dominant species
P1	**1**	37°33'36.39"N	15°7'1.09"E	**Etna**	*Hyparrhenia hirta* subsp. *hirta*
P2	**1**	37°33'36.68"N	15°6'59.69"E	**Etna**	*Hyparrhenia hirta* subsp. *hirta*
P3	**1**	37°33'34.50"N	15°6'53.84"E	**Etna**	*Hyparrhenia hirta* subsp. *hirta*
P4	**1**	37°33'38.02"N	15°6'58.61"E	**Etna**	*Hyparrhenia hirta* subsp. *hirta*
P5	**1**	37°33'35.21"N	15°7'0.58"E	**Etna**	*Hyparrhenia hirta* subsp. *hirta*
P6	**2**	38°12'3.98"N	13°18'8.97"E	**Palermo**	*Hyparrhenia hirta* subsp. *hirta*
P7	**2**	38°10'33.10"N	13°20'12.09"E	**Palermo**	*Hyparrhenia hirta* subsp. *hirta*
P8	**2**	38° 9'19.51"N	13° 6'51.44"E	**Palermo**	*Hyparrhenia hirta* subsp. *hirta*
P9	**2**	38° 5'55.00"N	13°18'34.00"E	**Palermo**	*Hyparrhenia hirta* subsp. *hirta*
P10	**2**	38° 9'20.81"N	13°21'46.60"E	**Palermo**	*Hyparrhenia hirta* subsp. *hirta*
P11	**1**	37°56'37.96"N	15°42'12.81"E	**Calabria**	*Hyparrhenia hirta* subsp. *hirta*
P12	**2**	38°27'18.97"N	15°58'20.25"E	**Calabria**	*Hyparrhenia hirta* subsp. *hirta*
P13	**1**	38°57'49.56"N	16° 9'7.39"E	**Calabria**	*Hyparrhenia hirta* subsp. *hirta*
P14	**1**	38° 4'21.09"N	15°42'44.59"E	**Calabria**	*Hyparrhenia hirta* subsp. *hirta*
P15	**1**	38°41'5.86"N	16°32'35.60"E	**Calabria**	*Hyparrhenia hirta* subsp. *hirta*
P16	**3**	37°31'49.48"N	15°5'57.70"E	**Etna**	*Cenchrus setaceus*
P17	**3**	37°31'48.44"N	15°5'59.66"E	**Etna**	*Cenchrus setaceus*
P18	**3**	37°31'49.30"N	15°5'58.03"E	**Etna**	*Cenchrus setaceus*
P19	**3**	37°31'48.35"N	15°5'49.67"E	**Etna**	*Cenchrus setaceus*
P20	**3**	37°31'50.01"N	15°5'44.56"E	**Etna**	*Cenchrus setaceus*
P21	**3**	38°12'17.29"N	13°18'21.89"E	**Palermo**	*Cenchrus setaceus*
P22	**3**	38°10'21.66"N	13°20'16.17"E	**Palermo**	*Cenchrus setaceus*
P23	**3**	38° 9'3.83"N	13° 7'2.39"E	**Palermo**	*Cenchrus setaceus*
P24	**3**	38° 5'55.99"N	13°18'34.99"E	**Palermo**	*Cenchrus setaceus*
P25	**3**	38° 9'17.27"N	13°21'40.53"E	**Palermo**	*Cenchrus setaceus*
P26	**3**	37°56'38.93"N	15°42'13.99"E	**Calabria**	*Cenchrus setaceus*
P27	**3**	38°27'19.40"N	15°58'20.60"E	**Calabria**	*Cenchrus setaceus*
P28	**3**	38°57'49.45"N	16° 9'7.52"E	**Calabria**	*Cenchrus setaceus*
P29	**3**	38° 4'20.83"N	15°42'44.86"E	**Calabria**	*Cenchrus setaceus*
P30	**3**	38°41'4.88"N	16°32'38.12"E	**Calabria**	*Cenchrus setaceus*

Mefford 2011). Ordination by Canonical Correspondence Analysis (CCA) took into account the bioclimatic variables at 30s resolution from WorldClim (Fick and Hijmans 2017). Quantum GIS software version 3.6 was used for the interpolation of the bioclimatic variables and plant communities.

Results

The investigated *Cenchrus setaceus* grasslands have, on average, an estimated coverage of 95%, while those with *H. hirta* have 90%; the communties with *C. setaceus* are more homogeneous with each other for this parameter than those with *H. hirta* (Standard deviation 6.7 vs. 9.03). There is no correlation between the vegetation coverage and the number of species present in the relevés (r = -0.09545). The classification of the relevés showed two main vegetation groups (Fig. 1). The first one (cluster A) including the *Hyparrhenia hirta* plant communities, belonging to *Hyparrhenietum hirto-pubescentis* A.& O.Bolòs & Br.-Bl. in A.& O. Bolòs 1950 (*Hyparrhenenion hirtae* alliance). Within this cluster, two subgroups can be distinguished: the first one includes the *Hyparrhenia hirta* communities of Eastern Sicily and Calabria, linked to volcanic or methamorphic substrata, while the second group (cluster 2) includes the *Hyparrhenia hirta* communities of Western Sicily, linked to carbonate substrates. The second one (cluster B) including the *Cenchrus setaceus* communities, belonging to *Pennisseto setacei-Hyparrhenietum hirtae* (*Aristido caerulescentis-Hyparrhenenion hirtae*). This cluster characterised by the dominance of *C. setaceus* does not show any community differentiation, probably linked to a floristic uniformity/similarity despite the diversity of geological substrate.

The ordination of the relevés obtained by CCA is displayed in Fig. 2. A marked correspondence was observed using cluster analysis in grouping three different communities. In particular, on the positive side of axis 1 there are the *H. hirta* communities of Etna and Calabria (BIO 1,6,8,11) and *H. hirta* community of Palermo (BIO 12,13,14,16,17,18,19) linked to thermophilous environmental conditions, while on the negative side of axis 1 are distributed the communities belonging to *C. setaceus* communities linked to thermo-xerophilous environmental conditions (BIO 2,3,7,15).

Overall, the floristic richness of the grasslands investigated is equal to 174 taxa (Supplementary material, Table 2). The species richness of *H. hirta* communities ranges between 16 and 51 taxa (mean = 25.3), and for *C. setaceus* communities ranges between 15 and 42 (mean = 26).

The diversity index of the *H. hirta* community shows an average Shannon-Wiener diversity index (H) of 1.94 (J = 0.6), and *C. setaceus* communities shows an average Shannon-Wiener diversity index (H) of 1.67 (J = 0.55).

Our results report for both grassland types (*H. hirta* and *C. setaceus* communities) that the most represented families are Asteraceae (18%-16% respectively), Fabaceae (17%-16% respectively) and Poaceae (13% for both). From a chorological viewpoint, most taxa show a Mediterranean distribution (40-42% respectively) and Euromediterranean (30-33% respectively). The dominant life form corresponds to therophytes (53-58% respectively) and hemicryptophytes (29%-24% respectively), while lower values were reached by chamaephytes, geophytes and nanophanerophytes.

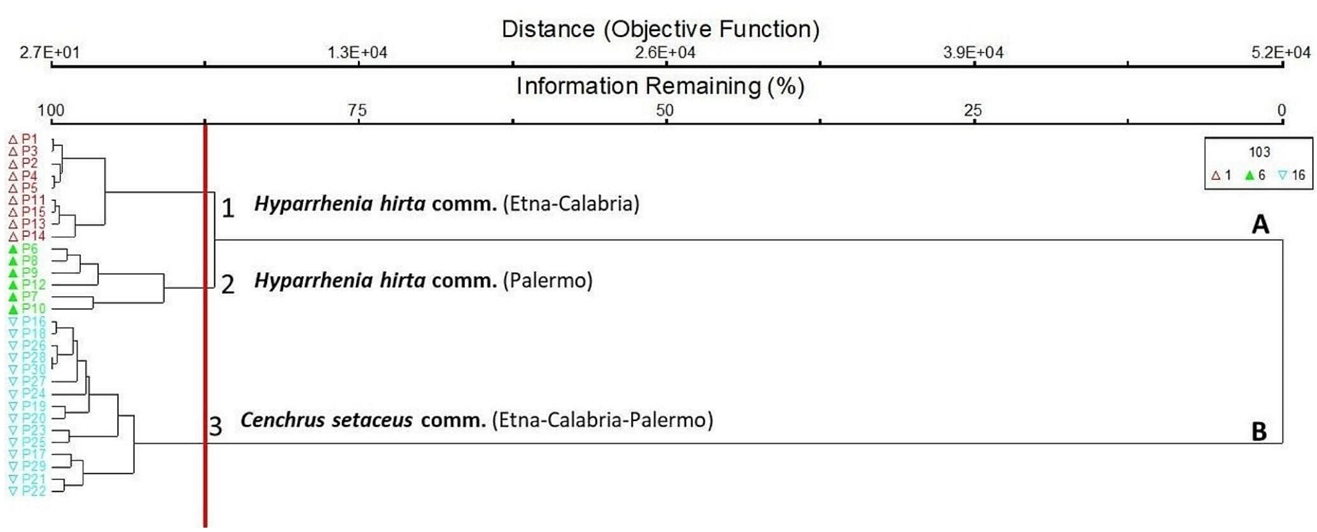

Fig. 1 Cluster analysis of the surveyed plant communites: **A**. *Hyparrhenia hirta* communities (1. Etna-Calabria; 2. Palermo); **B**. *Cenchrus setaceus* community (3. Etna-Calabria-Palermo). P1-P30 are sampling plots according to Table 1

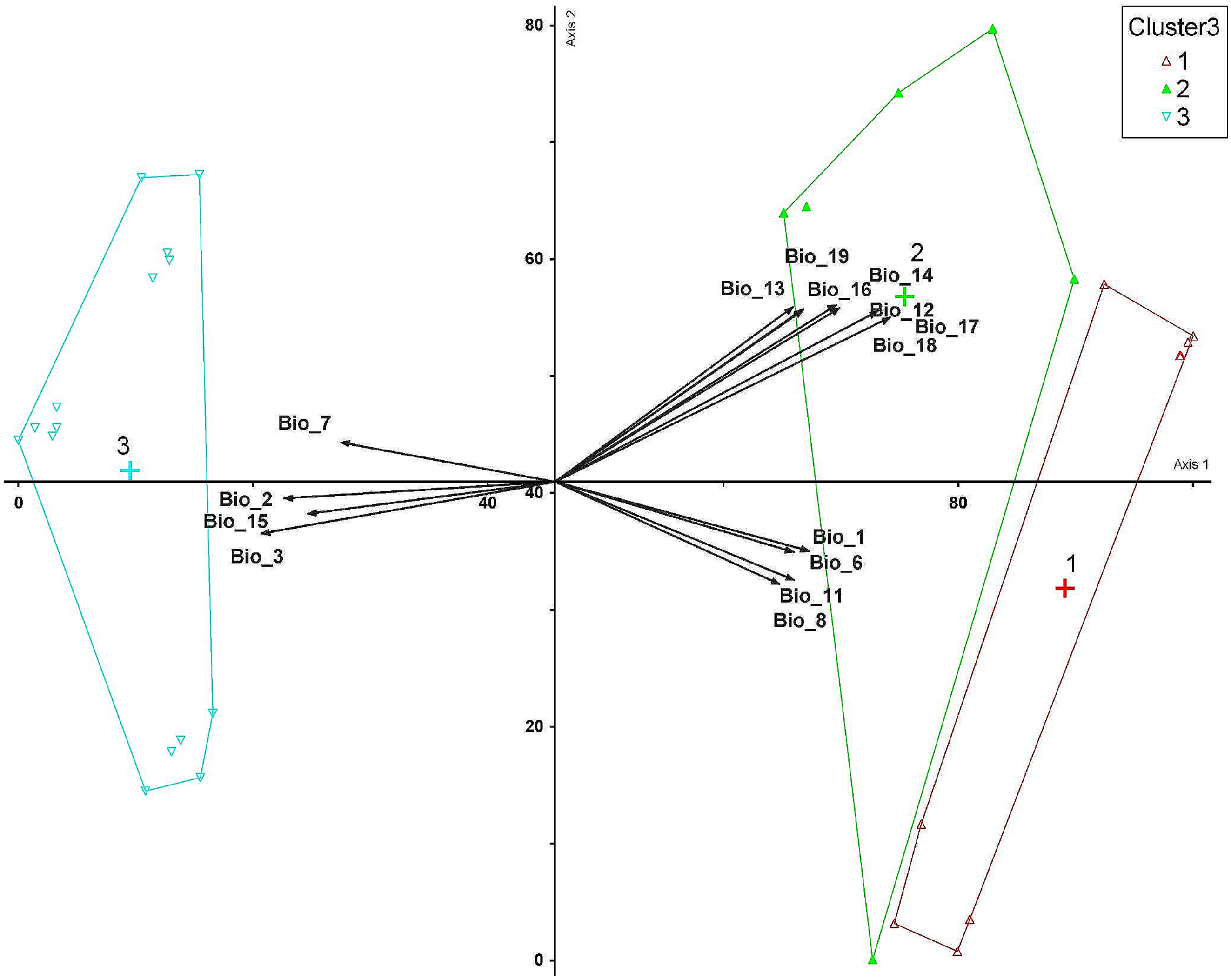

Fig. 2 CCA of the surveyed plant communities: Total variance ("inertia") in the species data: 3.08. Eigen-values: Axis 1: 0.647, Axis 2: 0.249, Axis 3: 0.227. Variance in species data % of variance explained, Axis 1, 21.0, Axis 2, 8.1, Axis 3, 7.3. Cumulative % explained Axis 1, 21.0, Axis 2, 29.0, Axis 3, 36.4. P1-P30 are sampling plots according to Table 1. Cluster 1 *Hyparrhenia hirta* (Etna-Calabria), Cluster 2 *Hyparrhenia hirta* (Palermo), Cluster 3 *Cenchrus setaceus* (Etna-Calabria-Palermo). Bioclimatic variables: BIO1 = Annual Mean Temperature; BIO2 = Mean Diurnal Range (Mean of monthly (max temp - min temp)); BIO3 = Isothermality (BIO2/BIO7) (×100); BIO4 = Temperature Seasonality (standard deviation ×100); BIO5 = Max Temperature of Warmest Month; BIO6 = Min Temperature of Coldest Month; BIO7 = Temperature Annual Range (BIO5-BIO6); BIO8 = Mean Temperature of Wettest Quarter; BIO9 = Mean Temperature of Driest Quarter; BIO10 = Mean Temperature of Warmest Quarter; BIO11 = Mean Temperature of Coldest Quarter; BIO12 = Annual Precipitation; BIO13 = Precipitation of Wettest Month; BIO14 = Precipitation of Driest Month; BIO15 = Precipitation Seasonality (Coefficient of Variation); BIO16 = Precipitation of Wettest Quarter; BIO17 = Precipitation of Driest Quarter; BIO18 = Precipitation of Warmest Quarter; BIO19 = Precipitation of Coldest Quarter

Discussion

Invasions of plants outside their native range are increasing by the day, and large numbers of alien species are being recorded in new territories (Musarella et al. 2024). Community resistance to invasions increases in proportion to its species richness, considered in terms of number of species (Elton 1958).

Mack et al. (2000) suggest that resistance to plant invasion may correlate more strongly with the maintenance of a multitiered plant canopy (architecture of the plant community) than with the actual number of species within the community. The *H. hirta* grasslands with an average of 25.3 taxa per relevé fall within the average of grasslands in the Mediterranean environment (Del Vecchio & al. 2017; Brullo et al. 2020). The plant canopy of *H. hirta* communities is made up of an upper herbaceous layer (up to 120 cm) which persists throughout the year and an underlying herbaceous layer (up to 30 cm) present only in winter and early spring. The plant canopy of *C. setaceus* has a lower upper herbaceous layer

(80–90 cm) throughout the year and a similar underlying herbaceous layer (up to 30 cm) present in winter and early spring.

The two dry grassland communities here studied show different ecological needs, diversity/floristic composition and trends. Both communities represent aspects of forest-shrub vegetation regression, both due to direct human pressures (Huang et al. 2018; Molina et al. 2022). The *Hyparrhenietum hirto-pubescentis* A. & O.Bolòs & Br.-Bl. in A. & O.Bolòs 1950 grassland is widespread from the sea level up to 1000 m of altitude, within the thermomediterranean and mesomediterranean dry-subhumid belt, on slopes characterized by rocky outcrops and primitive soils. It is differentiated by the dominance of *H. hirta* which is usually associated with *Andropogon distachyos* L. and several xerophilous species belonging to *Hyparrhenion hirtae* alliance, as *Anethum piperitum* Ucria (=*Foeniculum vulgare* Mill. subsp. *piperitum* (Ucria) Bég.), *Ferula communis* L., *Thapsia garganica* L., *Convolvulus althaeoides* L., *Lathyrus clymenum* L. (=*Lathyrus articulatus* L.), etc. This phytocoenosis chiefly derives from the degradation of thermophilous oak woods or maquis belonging to the *Quercetea ilicis* class. Human disturbance (such as frequent fires, overgrazing, etc.) creates suitable conditions for the establishment of such community, which can also play an important role in the re-colonization processes of abandoned fields (Brullo et al. 2010).

The *Penniseto setacei-Hyparrhenietum hirtae* Gianguzzi, Ilardi & Raimondo (1996) is widespread on coastal territories of north-western Sicily (Gianguzzi et al. 1993) and eastern Sicily and Calabria and occurs up to 500 m a.s.l. This pioneer dry grassland is indifferent to the substrate and prefers abandoned fields, uncultivated ruderal areas and road sides within the Thermomediterranean dry bioclimatic belt. Physiognomically, it is differentiated by *C. setaceus* together with *L. clymenum, C. althaeoides, Dactylis glomerata* L. subsp. *hispanica* (Roth) Nyman, *Bituminaria bituminosa* (L.) C.H.Stirt., *Verbascum sinuatum* L., *Clinopodium nepeta* (L.) Kuntze, *Reichardia picroides* (L.) Roth, etc.

Northern Territory Government (2012) and EPPO (2023) report that *Cenchrus setaceus* vegetation in its evolutionary process tends to close itself and form almost monophitic communities, considerably reducing the community's diversity and floristic richness. Our results show that regarding the number of taxa per relevé the *C. setaceus* and *Hyparrenia hirta* communities have similar range (15–42 vs. 16–51) and similar mean (26.0 vs. 25.3). Correspondingly for the Shannon-Wiener diversity index (H) (1.67 vs. 1.94). Thus, from a numeric point of view the *C. setaceus* grasslands are not less rich than those with *H. hirta*. From a qualitative point of view, the average biological spectra of the two communities are almost identical. From the chorological point of view, the *H. hirta* community hosts 1.5% more endemic species than the *C. setaceus* one (2.07 vs. 0.57%), but this is limited to the occurrence of *Euphorbia ceratocarpa* Ten. in the relevés near Catania, and more wide-ranging species (29.05 vs. 27.67%). The percentage variations are, however, small. The communities with *H. hirta* on the two different geological substrata (carbonate and metamorphic) differ floristically while the communities with *C. setaceus* are more homogeneous despite the differentiation of substrates. *C. setaceus* is not a true "Transformer alien" according to the definition by Richardson et al. (2000); it occupies large areas but performs the same role as fire promoter and sediment stabiliser as *H. hirta* that it is gradually replacing. As already reported by Czarniecka-Wiera et al. (2019) from Central Europe, also in a Mediterranean habitat we found no evidence that the effect of dominance for alien species is stronger than for native ones.

Conclusions

This study finds that, numerically, communities dominated by *Cenchrus setaceus* are not significantly less species-rich compared to those dominated by *H. hirta*. Furthermore, from a qualitative perspective, the two communities show remarkable similarities in terms of biological spectra, chorological distribution, and life forms of the species present. This suggests that the impact of *C. setaceus* dominance on species richness is not as pronounced.

The present findings have implications for the conservation and management of these Mediterranean dry grassland communities. While *C. setaceus* is replacing native species and altering community dynamics, it is not necessarily leading to a drastic loss of species richness. However, the potential ecological impacts of this invasion, such as altered ecosystem functions, changes in plant-animal interactions, and the potential displacement of rarer species, warrant continued attention. This study, albeit on a small scale, has also highlighted the ecological and floristic differences between alien and native plant communities and the distinction of the components of the invasion success that are useful for understanding and predicting the spread of the alien community on natural habitats (Hulme et al. 2013).

In light of these findings, further research is recommended to explore the impacts of invasive species on more complex plant communities and to investigate the dynamics of other invasive-native pairs. Additionally, ongoing monitoring and management efforts are crucial to understanding the long-term consequences of *C. setaceus* invasion on these important habitats and to inform effective conservation strategies. As the threat of invasive species continues to loom over these ecosystems, collaboration between researchers, land managers, and policymakers is essential to maintain the ecological integrity and biodiversity of Mediterranean dry grasslands.

Supplementary Information The online version contains supplementary material available at https://doi.org/10.1007/s42535-024-00871-x.

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Data availability Data underlying this manuscript are provided in the supplementary material.

Declarations

Conflict of interest The authors declare no competing interests.

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