BOTANY LETTERS
https://doi.org/10.1080/23818107.2020.1802775

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A preliminary checklist of the alien flora of Algeria (North Africa): taxonomy, traits and invasiveness potential

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ABSTRACT

Biological invasions are permanent threat to biodiversity hotspots such as the Mediterranean Basin. However, research effort on alien species has been uneven so far and most countries of North Africa such as Algeria has not yet been the subject of a comprehensive inventory of introduced, naturalized and invasive species. Thus, the present study was undertaken in order to improve our knowledge and to propose a first checklist of alien plants present in Algeria, including invasive and potentially invasive plants. This work aims to make an inventory of all available data on the alien flora present in Algeria, and to carry out preliminary quantitative and qualitative analyses (number of taxa, taxonomic composition, life forms, geographical origins, types of habitats colonized, degree of naturalization). The present review provides a global list of 211 vascular species of alien plants, belonging to 151 genera and 51 families. Most of them originated from North America (31.3%) and the Mediterranean Basin (19.4%). Nearly half (43%) of alien species are therophytes and most of them occur in highly disturbed biotopes (62%), such as arable fields (44.5%) or ruderal habitats, including rubble (17.5%). Introduced plants for ornamental purposes account for almost half (43.6%) of the alien flora. A large proportion (51.2%) of alien species is naturalized in Algeria, with about 16% considered as invasive or potentially invasive. However, the actual impact of these alien species on plant communities and ecosystems deserves urgent assessment with specific studies on impact at the community and the ecosystem levels.

ARTICLE HISTORY
Received 13 April 2020
Accepted 23 July 2020

KEYWORDS
Algeria; alien flora; introduced flora; invasive species; Mediterranean region; naturalized plants; plant traits; species list

Introduction

During the last three decades, the study of alien plants received an increasing attention from ecologists around the world, because of their adverse effects on native biota and human economies (Lodge 1993; Williamson 1996; Vilà et al. 2010; van Kleunen et al. 2015; Weber 2017). The risks are all the more important in ecosystems of the Mediterranean region, which can be considered more prone to invasion than similar ecosystems on other continents (Di Castri 1990; Brunel 2003; Lambinon 2005; Gritti et al. 2006; Dal Cin D'Agata et al. 2009; Bresch et al. 2013; Mayoral et al. 2018). A sound strategy to mitigate the risk of invasive alien plants starts with risk assessment and prioritization tools in order to identify which species should be managed in priority (Branquart et al. 2016). A first step to achieve this objective is to collect information on all alien plants present on a territory, including geographical origin, biology, ecology, pathways of introduction, and degree of naturalization (Verloove and Sánchez Gullón 2008).

Most Mediterranean countries have now established a list of alien plants (e.g. Sanz Elorza et al. 2004; Boršić et al. 2008; Arianoutsou et al. 2010; Stešević and Petrović 2010; Celesti-Grapow et al. 2011; Almeida and Freitas 2012; Galasso et al. 2018). However, there is still a lack of quantitative data on alien flora for some parts of the world (Ansong et al. 2018; van Kleunen et al. 2018a). This is especially the case for North Africa that have so far received little attention. Moreover, existing floras of this area are incomplete or obsolete, e.g. in Algeria the last flora dates back to the sixties (Quézel and Santa 1962–1963). This makes it difficult to evaluate the importance of alien species both qualitatively and quantitatively.

Some previous works on alien flora can however be cited for North Africa (Battandier 1895; Ducellier and Maire 1923, 1925; Le Floc'h et al. 1990; Vilà et al. 1999), but in Algeria, with the exception of recent observations from Zeddam (2008), Greuter and Raus (2008, 2009, 2010, 2011, 2012), EPPO (2010, 2014), Kazi Tani et al. (2012), Véla et al. (2013), and Sakhraoui et al. (2019), no global synthesis for alien plants has been undertaken. Therefore, there is an urgent need to list and collect data on the diversity of alien species in Algeria, some of which are likely to develop invasive behavior (Lambinon 2005; Brunel

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Published online 13 Aug 2020

et al. 2010). By establishing a first checklist, the present study represents an important milestone to start a new dynamic of alien species inventory with regular updates for the Algerian territory. In addition to providing a checklist, this study also provides a first assessment of their impact on natural and semi-natural habitats.

Materials and methods

Terminology

The checklist covers alien flora to Algeria that correspond to all plant taxa whose presence in Algeria is due to "intentional or accidental introduction as a result of human activity" (Richardson et al. 2000). To be included in the checklist, taxa should i) have been introduced (or presumed to be introduced) through activities related to humans or their domestic animals, whether intentionally or not, and ii) have been found in the wild (Webb 1985; Pyšek 1995; Krigas and Kokkini 2004; Campos et al. 2004; Lambinon 2005). Therefore, alien species exclusively cultivated or planted without clear evidence of escape or naturalization (Kowarik 1995; Wade 1997; Starfinger 1998; Richardson et al. 2000; Celesti Grapow et al. 2001; Vilà et al. 2001; Krigas and Kokkini 2004; Paradis et al. 2008) are not considered, even those cultivated on a large scale. Among alien plants found in the wild in Algeria, we used the classical distinction between *naturalized* and *casual* plants. *Naturalized plants* reproduce consistently and sustain populations over many life cycles and can eventually disperse over long distances without direct intervention by humans (Richardson et al. 2000). *Casual plants* are alien plants that are sometimes found in the wild, may reproduce occasionally in an area, but do not have established self-sustaining populations yet (Richardson et al. 2000). Otherwise, *invasive plants* are a subset of naturalized plants (Pyšek et al. 2004), they have potential to create large populations and spread rather quickly over a large area (Richardson et al. 2000). To give a species a naturalization status (casual, naturalized and invasive), we carried out a critical evaluation of the literature already published, based on our own field observations and our expertise.

Finally, a distinction is traditionally made according to the residence time of the species: archaeophytes were introduced before 1500 and neophytes were introduced after 1500 (Brun 2007). We included both archaeophytes and neophytes in the checklist although we are aware that there are probably more archaeophyte species in Algeria. However, there are no sources of data that allow us to date the arrival of these species, and evidence is often lacking to distinguish between native and old introductions.

Methodology and data sources

In this work, our first goal was to make an inventory of the alien flora of Algeria and to characterize it in terms of number of taxa, taxonomic composition, life forms and several other traits (see below). For this purpose, we made a comprehensive compilation of all vascular plants known as alien species in Algeria, and which are truly naturalized or at least casual, based on the main references on Algerian floras (Poiret 1789; Desfontaines 1798–1799; Munby 1847; Battandier and Trabut 1888–1890, 1895, 1902; Maire 1952–1987; Quézel and Santa 1962–1963) and the electronic version of the "New flora of Algeria" (https://efloramaghreb.org), improved by information available in other floras and basic documents (Gubb 1909, 1913; Lapie and Maige 1914; Ducellier and Maire 1923, 1925; Greuter et al. 1984–2008; Somon 1987; Le Floc'h et al. 1990; Le Houérou 1995; Vilà et al. 1999; Dobignard and Chatelain 2010–2013), and our personal observations in the field since 1999. We matched the literature data with information available on these plants in the key databases, such as Euro+Med PlantBase (http://www.emplantbase.org/home.html) and African Plant Database (https://www.ville-ge.ch/musinfo/bd/cjb/africa). We used the APD database, which specifies the native or introduced status (cultivated, weed or naturalized), of all plants present in Algeria, as a priority source. We checked the information with data from Euro+Med database, in particular the presence and status at the level of the entire Mediterranean basin and Europe (native included archaeophyte, alien with status unknown, naturalized, casual). Based on our expertise, we made a critical analysis for each species whose data are divergent or even contradictory between the two databases.

We gathered all the information available from the literature, and a database was made including all recorded alien plant species with their corresponding scientific names and the following biological traits: life form, geographical origin, introduction pathways, status and degree of naturalization, geographical distribution in Algeria, type of habitats colonized, and, as much as possible, the dynamic of each plant species (current or potential level of invasion in Algeria). The nomenclature of taxa follows the index of Dobignard and Chatelain 2010–2013), and the African Plant Database, an international source, is used as the taxonomic backbone. Names of the families of Angiosperms follow APG III (Chase and Reveal 2009; Haston et al. 2009). The life forms (or biological types) of the alien plant taxa are given according to Raunkiaer (1934), Ellenberg and Müller-Dombois (1967), Blanca et al. (2011) and Tison et al. (2014). We distinguished nine categories: therophytes, geophytes, hemicryptophytes, chamaephytes, nanophanerophytes and phanerophytes. In addition to these classical Raunkiaer's life forms, we considered as

distinct biological types: parasitic therophytes, climbers and succulents. The chorology of taxa is mainly based on the critical comparison of the information provided by Greuter et al. (1984–2008), Tutin et al. (1964–1993), Blanca et al. (2011), Tison et al. (2014), and the one available in the POWO database (http://www.plantsoftheworldonline.org). Data on global distribution of species as naturalized and information on naturalization outside their native range were extracted from Dobignard and Chatelain 2010–2013, APD and Euro+Med databases and verified by using floras and field surveys. The deliberate (ornamental and other uses) or accidental introduction was determined according to the literature and especially according to the knowledge of the proven or potential interests and uses of these taxa in Algeria. Le Houérou (1995) gives a large list of species introduced in North Africa with their pathways, and Houmani (1997) specifically for the ornamental pathway. On the other hand, a large number of alien plants considered in this work, were formerly introduced without any doubt for an ornamental purpose or for other utilities at the level of the botanical garden of Algiers (cf. SGA 1875; Gubb 1909, 1913; Carra and Gueit 1952).

The geographical distribution through the four major natural zones of Algeria (coastal strip, mountainous tellian zone, steppe and high plains zone and finally the Saharan zone) and the types of habitats (woodlands and forests, maquis and scrubs, wetlands and riverine habitats, meadows, grasslands, coasts and sand dunes, rocky habitats, fields and cultivated lands, wastelands and ruderal habitats), where each species has been established in Algeria, were given according to Algerian floras, mainly from Maire (1952–1987) and Quézel and Santa (1962–1963). Habitats were differentiated into natural habitats, semi-natural habitats and human-made or anthropogenic habitats (Krigas and Kokkini 2004; Lysenko 2010). According to synanthropic plant classifications developed by central Europeans authors (Holub and Jirásek 1967; Schroeder 1969; Kornas 1990; Pyšek et al. 2004), we distinguished epoecophytes, plants only established in ruderal and/or cultivated habitats, hemiagryophytes, plants able to establish in semi-natural habitats and holoagriophytes, plants able to establish in natural habitats.

Finally, we have established a preliminary list of invasive or potentially invasive plants in Algeria, based on the behavior of such species in other regions of the world (Lambdon et al. 2008; Weber 2017), particularly in the Mediterranean Basin (Brunel 2003; Brunel and Tison 2005; Hulme et al. 2008; Brunel et al. 2010), and our *in situ* observations. Although relatively imprecise, invasiveness elsewhere, particularly under the same climate, is considered as a good and robust predictor of invasiveness (Brunel and Tison 2005; Rejmánek et al. 2013).

Results

Checklist and number of alien plant species

In Algeria, this study allowed us to record 211 alien plants taxa (206 species and 5 subspecies, excluding autonyms), presented in Table 1, with the family, the life form, the geographical origin of each plant, introduction pathways, the distribution in Algeria, habitats colonized (or synanthropic types), and their status of naturalization. All the alien plants taxa recorded here are reported for Algeria in the two main databases (African Plant Database and Euro+Med PlantBase), except the following taxa: *Hibiscus cannabinus* L., *Amaranthus muricatus* (Gillies ex Moq.) Hieron., *Pistacia vera* L., *Solanum fastigiatum* Willd., *Polygonum baldschuanicum* Regel, and *Leucaena leucocephala* subsp. *glabrata* (Rose) Zárate.

Species degree of naturalization

An analysis according to the degree of naturalization of the alien flora (see Richardson et al. 2000) showed that 108 taxa can be classified as naturalized (in the sense that they can reproduce spontaneously over long periods), which represents 51.2% of all alien plants recorded in this work. The casual species (which includes mostly weeds that were introduced as contaminants of crop seeds, and alien plants escaping from cultivation) represented 36% (76 taxa). There is a low percentage of alien plants (27 taxa, 12.8%) whose naturalization status is currently unknown, and it is not possible to assess properly their degree of naturalization.

Taxonomic affiliation

Alien plants in Algeria are distributed among a large number of families (51) and genera (151). They belong mainly to angiosperms/eudicots (185 taxa, 128 genera, 43 families), followed by monocotyledons by far (25 species, 21 genera, 7 families), while gymnosperms are recorded with only one species (*Cupressus sempervirens* L.) and ferns and allies are not represented. Although widespread in the landscapes, *Pinus pinea* L. is considered as only cultivated in our case. This is why we did not include it in this study, unlike Vila et al. (1999).

There are 17 families with more than three alien species each, in particular *Fabaceae* (28 taxa), *Asteraceae* (26), *Amaranthaceae* (17), *Brassicaceae* (16), *Poaceae* (13) and *Solanaceae* (12). These six families account for more than half (53%) of alien species, while 33 families are represented with only one or two alien species (Figure 1). Families with the largest number of alien plants belong to the largest families around the world. However, the taxonomic composition of alien flora is not fully proportional to

Table 1. Checklist of alien plant species recorded in Algeria.

Taxa (accepted names according to APD)	Families (APG III)	Life forms	Origin (chorology)	Status	Distribution in Algeria				Synanthropic type (habitats)	Introduction pathways
					Lit	TA	St	Sah		
Abelmoschus esculentus (L.) Moench var. *esculentus*	*Malvaceae*	T(H)	Paleotropical	C					epoe	other uses
Abutilon theophrasti Medik.	*Malvaceae*	T	Asiatic	N	+	+			epoe	other uses
Acacia farnesiana (L.) Willd.	*Fabaceae*	Ph	Neotropical	N					epoe	ornamental
Acacia karroo Hayne	*Fabaceae*	Ph	S African	N	+				hemiagr	ornamental
Acacia mearnsii De Wild.	*Fabaceae*	Ph	Australian	N	+				epoe	ornamental
Acacia melanoxylon R. Br.	*Fabaceae*	Ph	Australian	N	+				epoe	ornamental
Acacia saligna (Labill.) H.L. Wendl.	*Fabaceae*	Ph	Australian	N					epoe	ornamental
Agave americana L.	*Asparagaceae*	Ph(Ch) succ	N American	N	+	+			epoe	ornamental
Agave sisalana Perrine	*Asparagaceae*	Ph(Ch) succ	N American	U	+				hemiagr	ornamental
Ageratina adenophora (Spreng.) R. M. King & H. Rob.	*Asteraceae*	H	N American	N	+				epoe	ornamental
Agrostemma githago L.	*Caryophyllaceae*	T	E Mediterranean	C	+	+			epoe	unintentional
Ailanthus altissima (Mill.) Swingle	*Simaroubaceae*	Ph	E Asiatic	N	+				holoagr	ornamental
Alcea rosea L.	*Malvaceae*	H	Tropical	C	+	+			epoe	ornamental
Aloe vera (L.) Burm. f.	*Xanthorrhoeaceae*	NPh succ	S African	N	+			+	epoe	ornamental
Althaea cannabina L.	*Malvaceae*	H	E Mediterranean	U	+	+			hemiagr	unintentional
Amaranthus caudatus L.	*Amaranthaceae*	T	Subtropical	C	+	+			epoe	ornamental
Amaranthus muricatus (Gillies ex Moq.) Hieron.	*Amaranthaceae*	H(G)	S American	C	+				ergasio	unintentional
Amaranthus tricolor L.	*Amaranthaceae*	T	S Asiatic	C	+	+			epoe	ornamental
Amaranthus viridis L.	*Amaranthaceae*	T	S American	C	+				epoe	other uses
Ambrosia artemisiifolia L.	*Asteraceae*	T	N American	N	+				epoe	unintentional
Ambrosia maritima L.	*Asteraceae*	T	E Mediterranean	C	+				hemiagr	unintentional
Ambrosia psilostachya DC.	*Asteraceae*	G	N American	N	+				epoe	unintentional
Anchusa ovata Lehm.	*Boraginaceae*	T	E Mediterranean	U	+				epoe	unintentional
Araujia sericifera Brot.	*Apocynaceae*	Ph cl	S American	U	+				epoe	ornamental
Artemisia verlotiorum Lamotte	*Asteraceae*	G(H)	E Asiatic	N	+	+	+		holoagr	unintentional
Asparagus setaceus (Kunth) Jessop	*Asparagaceae*	G	S African	U	+				epoe	ornamental
Atriplex lindleyi subsp. *inflata* (F. Muell.) Paul G. Wilson	*Amaranthaceae*	Ch	Australian	N	+	+	+		epoe	other uses
Atriplex nummularia Lindl. in Mitchell	*Amaranthaceae*	Ph	Australian	N	+	+	+		epoe	ornamental
Atriplex semibaccata R. Br.	*Amaranthaceae*	Ch(H)	Australian	N	+	+	+		epoe	other uses
Bassia indica (Wight) A.J. Scott	*Amaranthaceae*	T(H)	SW Asiatic	N					epoe	other uses
Bassia scoparia (L.) A.J. Scott subsp. *scoparia*	*Amaranthaceae*	T	C Asiatic	C	+				epoe	ornamental
Bidens pilosa L.	*Asteraceae*	T	S American	C	+				epoe	unintentional
Brassica rapa (L.) L.	*Brassicaceae*	T(H)	S Asiatic	U	+	+			epoe	other uses
Bromus catharticus Vahl	*Poaceae*	H	S American	N	+				epoe	other uses
Bromus secalinus L.	*Poaceae*	T	Eurasiatic	C	+				epoe	unintentional
Broussonetia papyrifera (L.) L'Hér. ex Vent.	*Moraceae*	Ph	E Asiatic	C	+				epoe	ornamental
Brugmansia suaveolens (Humb. & Bonpl. ex Willd.) Bercht. & C. Presl	*Solanaceae*	Ph	S American	C	+				epoe	ornamental
Cardiospermum grandiflorum Sw.	*Sapindaceae*	H	S American	N	+				epoe	ornamental
Carpobrotus acinaciformis (L.) Bolus	*Aizoaceae*	Ch succ	S African	N	+				hemiagr	ornamental
Carpobrotus edulis (L.) N.E. Br.	*Aizoaceae*	Ch succ	S African	N	+				hemiagr	ornamental
Casuarina cunninghamiana Miq.	*Casuarinaceae*	Ph	Australian	U	+				epoe	ornamental
Cenchrus longisetus M.C. Johnst.	*Poaceae*	H	E African	N	+				epoe	ornamental
Centaurea nigra L. subsp. *nigra*	*Asteraceae*	H	European	C	+				epoe	unintentional
Cestrum parquii L'Hér.	*Solanaceae*	NPh	S American	N					epoe	ornamental
Chasmanthe floribunda (Salisb.) N.E. Br. var. *floribunda*	*Iridaceae*	G	S African	U	+				epoe	ornamental
Chenopodium ambrosioides L.	*Amaranthaceae*	H(T)	N American	N	+	+			epoe	unintentional
Chenopodium botrys L.	*Amaranthaceae*	T	Eurasiatic	C	+				hemiagr	unintentional
Chenopodium ficifolium Sm.	*Amaranthaceae*	T	Eurasiatic	C	+				ergasio	unintentional
Chenopodium giganteum D. Don	*Amaranthaceae*	T	S Asiatic	N	+		+		epoe	ornamental
Chenopodium glaucum L.	*Amaranthaceae*	T	Subcosmopolitan	C	+				ergasio	unintentional
Chenopodium multifidum L.	*Amaranthaceae*	T(H)	S American	N	+				epoe	unintentional
Chenopodium urbicum L.	*Amaranthaceae*	T	Subcosmopolitan	N	+		+		epoe	unintentional
Chloris gayana Kunth	*Poaceae*	H(G)	Paleotropical	N	+			+	holoagr	ornamental
Chorispora tenella (Pall.) DC.	*Brassicaceae*	T	Asiatic	C	+				ergasio	unintentional
Cicer arietinum L.	*Fabaceae*	T	E Mediterranean	C					epoe	other uses
Colocasia esculenta (L.) Schott	*Araceae*	G	Tropical	N	+				holoagr	ornamental
Commelina chamissonis Klotzsch ex C.B. Clarke	*Commelinaceae*	T	S Asiatic	N	+				epoe	ornamental
Corchorus olitorius L.	*Malvaceae*	T	Tropical	C				+	epoe	other uses
Coriandrum sativum L.	*Apiaceae*	T	SW Asiatic	N					epoe	other uses
Cotula coronopifolia L.	*Asteraceae*	T	S African	N	+				holoagr	unintentional
Crepis bursifolia L.	*Asteraceae*	H	Italian	N	+	+			epoe	unintentional
Cuminum cyminum L.	*Apiaceae*	T	SW Asiatic	N	+	+	+		epoe	other uses
Cupressus sempervirens L.	*Cupressaceae*	Ph	E Mediterranean	U	+				epoe	ornamental

(*Continued*)

Table 1. (Continued).

Taxa (accepted names according to APD)	Families (APG III)	Life forms	Origin (chorology)	Status	Distribution in Algeria				Synanthropic type (habitats)	Introduction pathways
					Lit	TA	St	Sah		
Cuscuta campestris Yunck.	*Convolvulaceae*	T par	N American	N		+			ergasio	unintentional
Cuscuta scandens subsp. *cesatiana* (Bertol.) Soó	*Convolvulaceae*	T par	S European	C	+	+			epoe	unintentional
Cuscuta suaveolens Ser.	*Convolvulaceae*	T par	S American	N	+	+			epoe	unintentional
Cyanus segetum Hill	*Asteraceae*	T	Subcosmopolitan	C					epoe	unintentional
Datura metel L.	*Solanaceae*	T	N American	N	+		+		epoe	ornamental
Delairea odorata Lem.	*Asteraceae*	Ch(H) cl	S African	N	+	+			epoe	ornamental
Echinophora spinosa L.	*Apiaceae*	H	SW Mediterranean	C	+				hemiagr	unintentional
Echium vulgare L. subsp. *vulgare*	*Boraginaceae*	H	European	C	+				ergasio	unintentional
Elaeagnus angustifolia L.	*Elaeagnaceae*	Ph	C Asiatic	N	+	+	+		epoe	ornamental
Eleusine indica (L.) Gaertn. subsp. *indica*	*Poaceae*	T	Pantropical	C	+				epoe	unintentional
Enarthrocarpus lyratus (Forssk.) DC.	*Brassicaceae*	T	E Mediterranean	C	+				ergasio	unintentional
Erigeron bonariensis L.	*Asteraceae*	T	S American	N	+	+	+	+	epoe	unintentional
Erigeron canadensis L.	*Asteraceae*	T(H)	N American	N	+	+	+		holoagr	unintentional
Erigeron karvinskianus DC.	*Asteraceae*	H	Neotropical	N	+				hemiagr	ornamental
Erigeron sumatrensis Retz.	*Asteraceae*	T	S American	N	+	+	+		holoagr	unintentional
Erucaria hispanica (L.) Druce	*Brassicaceae*	T	E Mediterranean	N	+				ergasio	unintentional
Erysimum cheiranthoides L.	*Brassicaceae*	T	Circumboreal	C			+		ergasio	unintentional
Erysimum repandum L.	*Brassicaceae*	T	Mediterranean	C	+				ergasio	unintentional
Eucalyptus camaldulensis Dehnh.	*Myrtaceae*	Ph	Australian	C	+				holoagr	ornamental
Euphorbia maculata L.	*Euphorbiaceae*	T	N American	N	+				hemiagr	unintentional
Euphorbia petiolata Banks & Sol. var. *petiolata*	*Euphorbiaceae*	T	E Mediterranean	C	+				ergasio	unintentional
Euphorbia prostrata Aiton	*Euphorbiaceae*	T	S American	N	+				epoe	unintentional
Euphorbia serpens Kunth	*Euphorbiaceae*	T	S American	N	+				epoe	unintentional
Fagopyrum esculentum Moench	*Polygonaceae*	T	E Asiatic	C			+		epoe	other uses
Ficus carica L. subsp. *carica*	*Moraceae*	Ph	W Asiatic	N	+	+			epoe	ornamental
Galinsoga parviflora Cav.	*Asteraceae*	T	S American	N	+	+			epoe	unintentional
Glycyrrhiza glabra L.	*Fabaceae*	G(H)	E Mediterranean	C				+	epoe	other uses
Gnaphalium antillanum Urb.	*Asteraceae*	T	N American	U	+				holoagr	unintentional
Gundelia tournefortii L.	*Asteraceae*	H	E Mediterranean	C	+				ergasio	unintentional
Heliotropium curassavicum L.	*Boraginaceae*	Ch(H)	N American	N	+	+	+		holoagr	unintentional
Hibiscus cannabinus L.	*Malvaceae*	T	S Asiatic	C					epoe	ornamental
Hibiscus palustris L.	*Malvaceae*	H	N American	C	+				holoagr	ornamental
Iberis amara L.	*Brassicaceae*	T	European	C					ergasio	unintentional
Iberis pectinata Boiss. & Reut.	*Brassicaceae*	T	Ibero-maghrebian	C					ergasio	unintentional
Iberis umbellata L.	*Brassicaceae*	H(T)	S European	C					epoe	unintentional
Ibicella lutea (Lindl.) Van Eselt.	*Martyniaceae*	T	S American	N	+				hemiagr	unintentional
Ipomoea indica (Burm.) Merr.	*Convolvulaceae*	NPh	Neotropical	N	+				hemiagr	ornamental
Iris albicans Lange	*Iridaceae*	G	SW Asiatic	U	+				epoe	ornamental
Isatis aptera (Boiss. & Heldr.) Al-Shehbaz, Moazzeni & Mummenhoff	*Brassicaceae*	T	W Asiatic	N			+		epoe	unintentional
Jasminum officinale L.	*Oleaceae*	NPh cl	W Asiatic	N	+	+			hemiagr	ornamental
Kalanchoe daigremontiana Raym.-Hamet & H. Perrier	*Crassulaceae*	Ch succ	Madagascar	U	+				epoe	ornamental
Lantana camara L.	*Verbenaceae*	NPh	S American	N	+				epoe	ornamental
Lathyrus odoratus L.	*Fabaceae*	T(H)	SW Mediterranean	C					epoe	ornamental
Lathyrus sativus L.	*Fabaceae*	T	E Mediterranean	C	+				epoe	other uses
Legousia hybrida (L.) Delarbre	*Campanulaceae*	T	Palaeotemperate	U	+	+	+		epoe	unintentional
Legousia speculum-veneris (L.) Chaix	*Campanulaceae*	T	E Mediterranean	C	+				epoe	unintentional
Lens culinaris Medik. subsp. *culinaris*	*Fabaceae*	T	Eurasiatic	C	+				epoe	other uses
Lepidium didymum L	*Brassicaceae*	T(H)	N American	N	+				epoe	other uses
Lepidium perfoliatum L.	*Brassicaceae*	T(H)	Eurasiatic	C	+				epoe	unintentional
Lepidium sativum L. subsp. *sativum*	*Brassicaceae*	T	SW Asiatic	C	+	+	+	+	epoe	other uses
Leucaena leucocephala subsp. *glabrata* (Rose) Zárate	*Fabaceae*	Ph	Neotropical	N	+				epoe	ornamental
Linum tenuifolium auct.	*Linaceae*	Ch	E Mediterranean	U		+			hemiagr	unintentional
Linum usitatissimum L. subsp. *usitatissimum*	*Linaceae*	T	European	C	+	+	+		epoe	other uses
Lolium pratense (Huds.) I. Darbysh.	*Poaceae*	H	Eurasiatic	C	+				holoagr	other uses
Lolium remotum Schrank	*Poaceae*	T	Eurasiatic	C	+				epoe	unintentional
Lonicera japonica Thunb. ex Murray	*Caprifoliaceae*	NPh cl	E Asiatic	C	+				epoe	ornamental
Lupinus albus L. subsp. *albus*	*Fabaceae*	T	E Mediterranean	N	+				epoe	other uses
Lycium ferocissimum Miers	*Solanaceae*	NPh	E Asiatic	N	+	+		+	hemiagr	ornamental
Macfadyena unguis-cati (L.) A.H. Gentry	*Bignoniaceae*	Ph cl	S American	N	+				epoe	ornamental
Malva oxyloba Boiss.	*Malvaceae*	T	E Mediterranean	C	+				epoe	unintentional
Matricaria chamomilla L.	*Asteraceae*	T	SW Asiatic	U	+				epoe	ornamental
Matthiola incana (L.) R.Br. subsp. *incana*	*Brassicaceae*	Ch(NPh)	S European	N	+				hemiagr	ornamental
Medicago arborea L.	*Fabaceae*	NPh	SW Mediterranean	N	+				epoe	ornamental
Melilotus albus Medik.	*Fabaceae*	T(H)	Eurasiatic	C	+				ergasio	other uses

(*Continued*)

Table 1. (Continued).

Taxa (accepted names according to APD)	Families (APG III)	Life forms	Origin (chorology)	Status	Distribution in Algeria				Synanthropic type (habitats)	Introduction pathways
					Lit	TA	St	Sah		
Melilotus italicus (L.) Lam.	*Fabaceae*	T	Mediterranean	C	+				ergasio	unintentional
Mentha spicata L. subsp. *spicata*	*Lamiaceae*	H	E Mediterranean	C					epoe	other uses
Mesembryanthemum cordifolium L. f.	*Aizoaceae*	Ch succ	S African	N	+				epoe	ornamental
Mirabilis jalapa L.	*Nyctaginaceae*	H(G)	S American	U	+	+			hemiagr	ornamental
Nicotiana glauca Graham	*Solanaceae*	NPh(Ph)	S American	N	+	+	+		hemiagr	ornamental
Nothoscordum gracile (Dryand.) Stearn	*Amaryllidaceae*	G	S American	N	+		+		epoe	ornamental
Oenothera biennis L.	*Onagraceae*	H(T)	N American	N	+				holoagr	ornamental
Oenothera rosea L'Hér. ex Aiton	*Onograceae*	T	N American	N	+				epoe	ornamental
Onobrychis viciifolia Scop.	*Fabaceae*	H	E Mediterranean	N					epoe	other uses
Opuntia ficus-indica (L.) Mill.	*Cactaceae*	Ph succ	Neotropical	N	+	+			hemiagr	ornamental
Origanum majorana L.	*Lamiaceae*	H	E Mediterranean	N	+				epoe	other uses
Oxalis acetosella L.	*Oxalidaceae*	G(H)	Circumboreal	U					ergasio	unintentional
Oxalis articulata Savigny subsp. *articulata*	*Oxalidaceae*	G	S American	C	+	+			epoe	ornamental
Oxalis compressa L.f. var. *compressa*	*Oxalidaceae*	G	S African	N	+				epoe	unintentional
Oxalis debilis Kunth	*Oxalidaceae*	G	S American	N	+				epoe	unintentional
Oxalis pes-caprae L.	*Oxalidaceae*	G(H)	S African	N	+	+	+		epoe	unintentional
Oxalis purpurea L.	*Oxalidaceae*	G	S African	N	+				holoagr	ornamental
Paliurus spina-christi Mill.	*Rhamnaceae*	Ph	S European	C	+				hemiagr	other uses
Paraserianthes lophantha (Willd.) I.C. Nielsen subsp. *lophantha*	*Fabaceae*	Ph	Australian	N	+	+			holoagr	ornamental
Parthenocissus quinquefolia (L.) Planch.	*Vitaceae*	Ph cl	N American	N	+				epoe	ornamental
Paspalum dilatatum Poir.	*Poaceae*	G(H)	S American	N	+				epoe	unintentional
Paspalum distichum L.	*Poaceae*	G	Neosubtropical	N	+				holoagr	unintentional
Periploca graeca L.	*Apocynaceae*	Ph cl	S European	C	+				hemiagr	ornamental
Petroselinum crispum (Mill.) Fuss subsp. *crispum*	*Apiaceae*	H	European	N	+	+	+		hemiagr	other uses
Phacelia tanacetifolia Benth.	*Boraginaceae*	T	N American	C			+		epoe	ornamental
Phleum subulatum (Savi) Asch. & Graebn. subsp. *subulatum*	*Poaceae*	T	Mediterranean	C	+				hemiagr	unintentional
Phyla filiformis (Schrad.) Meikle	*Verbenaceae*	Ch(H)	S American	N	+	+			holoagr	ornamental
Physalis acutifolia (Miers) Sandw.	*Solanaceae*	T	N American	U			+		epoe	unintentional
Physalis alkekengi L.	*Solanaceae*	H	Eurasiatic	C					epoe	ornamental
Phytolacca americana L.	*Phytolaccaceae*	H(G)	N American	N	+				epoe	ornamental
Phytolacca dioica L.	*Phytolaccaceae*	Ph	S American	N	+				epoe	ornamental
Pistacia vera L.	*Anacardiaceae*	Ph	W Asiatic	C					epoe	other uses
Pisum sativum L. subsp. *sativum*	*Fabaceae*	T	Cosmopolitan	C	+				epoe	other uses
Poa compressa L.	*Poaceae*	H	Circumboreal	U	+				holoagr	unintentional
Podranea ricasoliana (Tanfani) Sprague	*Bignoniaceae*	Ph cl	S African	U	+				epoe	ornamental
Polygala myrtifolia L. var. *myrtifolia*	*Polygalaceae*	NPh	S African	N	+				hemiagr	ornamental
Polygonum baldschuanicum Regel	*Polygonaceae*	Ph cl	Temperate Asiatic	N					epoe	ornamental
Proboscidea louisianica (Mill.) Thell.	*Martyniaceae*	T	N American	C	+	+			ergasio	unintentional
Punica granatum L.	*Lythraceae*	Ph	SW Asiatic	N	+	+			epoe	ornamental
Reseda odorata L.	*Resedaceae*	T(H)	E Mediterranean	N	+				hemiagr	ornamental
Rhus coriaria L.	*Anacardiaceae*	Ph	Mediterranean	U	+	+			hemiagr	other uses
Ricinus communis L.	*Euphorbiaceae*	NPh(Ph)	Paleotropical	N	+	+	+	+	epoe	ornamental
Robinia pseudoacacia L.	*Fabaceae*	Ph	N American	N	+				holoagr	ornamental
Rubia tinctorum L.	*Rubiaceae*	H(G)	C Asiatic	N	+	+			epoe	other uses
Rumex patientia L.	*Polygonaceae*	H	European	C		+			ergasio	other uses
Salpichroa origanifolia (Lam.) Baill.	*Solanaceae*	NPh cl	S American	N	+				hemiagr	ornamental
Salvia fruticosa Mill.	*Lamiaceae*	Ch	E Mediterranean	N	+				epoe	ornamental
Salvia nemorosa L	*Lamiaceae*	H	Eurasiatic	C	+				epoe	unintentional
Salvia officinalis L.	*Lamiaceae*	Ch	W Asiatic	N					epoe	ornamental
Sambucus nigra L.	*Adoxaceae*	Ph	S European	N		+			hemiagr	ornamental
Senecio angulatus L.f.	*Asteraceae*	NPh cl succ	S African	U	+				hemiagr	ornamental
Setaria parviflora (Poir.) Kerguélen	*Poaceae*	H	American	N	+				epoe	unintentional
Silene dichotoma Ehrh.	*Caryophyllaceae*	T	S European	C			+		ergasio	unintentional
Silene longipetala Vent.	*Caryophyllaceae*	H	E Mediterranean	C	+				hemiagr	unintentional
Sisymbrium austriacum subsp. *hispanicum* (Jacq.) P.W. Ball & Heywood	*Brassicaceae*	H(T)	Iberian	N	+			+	epoe	unintentional
Solanum bonariense L.	*Solanaceae*	NPh	S American	N	+	+			epoe	ornamental
Solanum elaeagnifolium Cav.	*Solanaceae*	H	N American	N	+		+		epoe	ornamental
Solanum fastigiatum Willd.	*Solanaceae*	NPh	S American	C					epoe	ornamental
Solanum glaucophyllum Desf.	*Solanaceae*	NPh	S American	N	+				epoe	unintentional
Stenotaphrum secundatum (Walter) Kuntze	*Poaceae*	G	Neotropical	N	+				holoagr	ornamental
Sternbergia lutea (L.) Ker Gawl. ex Spreng.	*Amaryllidaceae*	G	Mediterranean	N	+	+	+		epoe	ornamental
Symphyotrichum squamatum (Spreng.) G.L. Nesom	*Asteraceae*	T(H)	S American	N	+	+	+	+	holoagr	unintentional
Symphytum bulbosum K.F. Schimp.	*Boraginaceae*	G	S European	C	+				holoagr	unintentional
Tanacetum parthenium (L.) Sch. Bip.	*Asteraceae*	H(G)	E Mediterranean	C	+	+			epoe	ornamental
Thlaspi arvense L.	*Brassicaceae*	T	Eurasiatic	C	+	+			epoe	unintentional
Trifolium hybridum L.	*Fabaceae*	H	Mediterranean	U	+				holoagr	unintentional

(*Continued*)

Table 1. (Continued).

Taxa (accepted names according to APD)	Families (APG III)	Life forms	Origin (chorology)	Status	Distribution in Algeria				Synanthropic type (habitats)	Introduction pathways
					Lit	TA	St	Sah		
Trigonella esculenta Willd.	*Fabaceae*	T	Mediterranean	C	+				ergasio	unintentional
Trigonella foenum-graecum L.	*Fabaceae*	T	SW Asiatic	N	+				epoe	other uses
Trigonella glabra Thunb.	*Fabaceae*	T	Asiatic	C	+				ergasio	unintentional
Trigonella laciniata L.	*Fabaceae*	T	Saharo-Arabian	C	+				ergasio	unintentional
Tropaeolum majus L.	*Tropaeolaceae*	G	S American	U	+				epoe	ornamental
Ulex europaeus L. subsp. *europaeus*	*Fabaceae*	Ch(NPh)	European	N	+				epoe	other uses
Verbesina encelioides (Cav.) Benth. & Hook.f. ex A. Gray subsp. *encelioides*	*Asteraceae*	T	N American	N	+				hemiagr	ornamental
Vicia ervilia (L.) Willd.	*Fabaceae*	T	E Mediterranean	N	+		+		epoe	other uses
Vicia faba L.	*Fabaceae*	T	SW Mediterranean	N					epoe	other uses
Vicia pannonica Crantz	*Fabaceae*	T	Mediterranean	C	+				epoe	unintentional
Vinca major L. subsp. *major*	*Apocynaceae*	Ch	Mediterranean	C	+				holoagr	ornamental
Xanthium orientale subsp. *italicum* (Moretti) Greuter	*Asteraceae*	T	S American	N	+	+			epoe	unintentional
Xanthium spinosum L.	*Asteraceae*	T(Ch)	S American	N	+	+	+		epoe	unintentional
Xanthium strumarium L. subsp. *strumarium*	*Asteraceae*	T	Subcosmopolitan	N	+	+	+		epoe	unintentional
Xylosalsola paletzkiana (Litv.) Akhani & Roalson	*Amaranthaceae*	NPh	C Asiatic	N				+	epoe	other uses
Yucca gloriosa L.	*Asparagaceae*	Ph	S American	U	+				hemiagr	ornamental
Zantedeschia aethiopica (L.) Spreng.	*Araceae*	G	S African	N	+				holoagr	ornamental
Ziziphus spina-christi (L.) Desf.	*Rhamnaceae*	Ph	SW Asiatic	N			+	+	epoe	other uses

Legends: Life forms according to Raunkiaer's system (1934): G = Geophyte, Ch = Chamaephyte, H = Hemicryptophyte, Ph = Phanerophyte, NPh = Nanophanerophyte, T = Therophyte, par = parasite, cl = climber, succ = succulent. Origin of the taxa: N = North, S = South, E = East, W = West, C = Central. Status: N = naturalized alien, C = casual alien, U = alien of unknown naturalization status. Distribution in Algeria: Lit = littoral, TA = tellian Atlas, St = steppe, Sah = Sahara. Synanthropic types according to Kornas classification (1990): hemiagr = hemiagriophyte, holoagr = holoagriophyte, ergasio = ergasiophygophyte, epoe = epoecophyte.

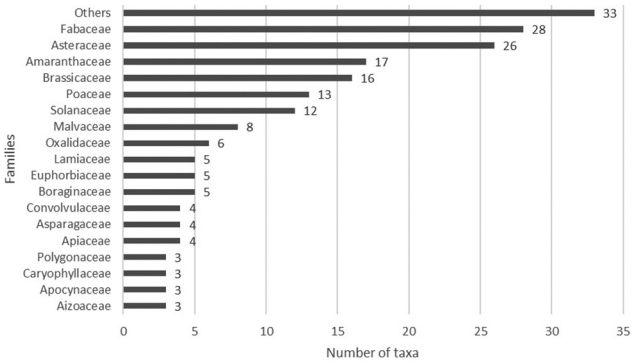

Figure 1. Families ordered according to the number of alien taxa they comprise in Algeria.

the global flora and other non-dominant families are important suppliers of alien plants, such as *Amaranthaceae, Solanaceae*, and to a lesser extent *Malvaceae* (Figure 2). These families are over-represented compared to the number expected by chance, while some of the large species-rich families are under-represented, e.g. *Poaceae, Caryopyllaceae, Lamiaceae, Apiaceae*.

Several genera are represented with more than three alien plants each. They are: *Oxalis* (6 taxa), *Chenopodium* (5 taxa), *Acacia* (5), *Amaranthus, Euphorbia, Erigeron, Trigonella, Solanum*, with 4 taxa each, *Xanthium, Ambrosia, Atriplex, Salvia, Vicia, Cuscuta, Iberis*, and *Lepidium*, with 3 taxa each.

Life forms

The life forms are distributed as follows in the alien flora of Algeria considered in this work (we have retained the most common life forms for any given species): therophytes and parasitic therophytes (90 taxa, 43%), hemicryptophytes (34, 16%), phanerophytes (24, 11%), nanophanerophytes (13, 6%), geophytes (21, 10%), chamaephytes (10, 5%), climbers

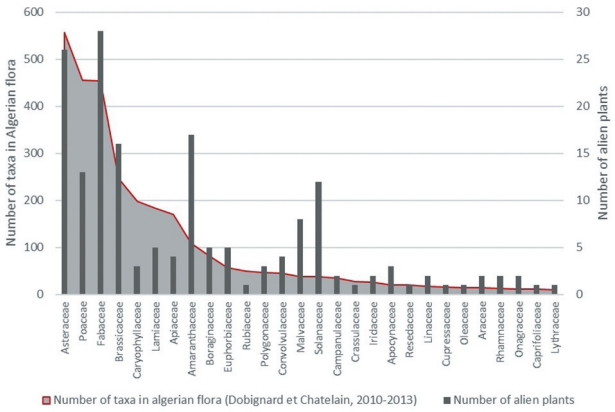

Figure 2. Number of alien plants compared with number of all plants (native and non-native) by families in Algerian flora (see Dobignard & Chatelain, 2013). Families are ordered from left to right according to the number of taxa in Algerian flora.

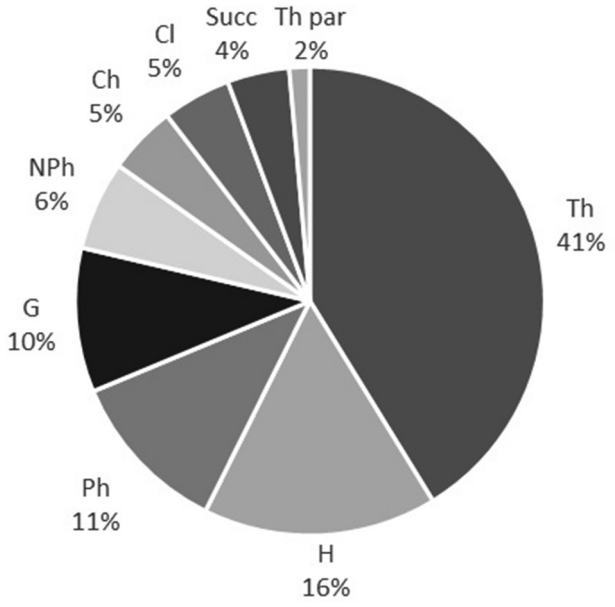

Figure 3. Life forms of alien flora of Algeria. Abbreviations: Ph = phanerophyte, NPh = nanophanerophyte, Ch = chamaephyte, H = hemicryptophyte, G = geophyte, Th = therophyte, Cl = climber, Succ = succulent, Par = parasite.

(10, 5%), and succulents (9, 4%). Annuals predominate clearly (Figure 3).

Geographical origins

With respect to the area of origin, we showed that most of the alien plants come from the Americas (Figure 4), with 31.3% of all taxa, distributed especially in South America (31 taxa, 14.7%) and North America (24, 11.4%), followed by the Mediterranean Basin (19.4%). To a lesser extent, they are also from Asia (16.1%), Africa (10%) and Australia (4.3%). Eurasia and Europe are represented with 4.3% and 7.1% respectively. Finally, 7.6% are currently spread over a very large distribution area (cosmopolitan, (sub)tropical and other). Cosmopolitan and subcosmopolitan plants can be labelled as anecophytes, i.e. plants that are alien throughout their known global range ("homeless plants", Zohary 1962) (Pyšek et al. 2012).

Distribution in Algeria

The geographical distribution of alien plants in Algeria clearly follows a North-South geographical gradient, with a regular decrease of alien plant diversity from littoral to Saharan region (Figure 5). From 82.9% (175 taxa) of alien plants present in the littoral region, one passes to a rate of 26% (55 taxa) for the region of the Tellian Atlas, then to 16.1% (34 taxa) for the steppic region of the high plains (including the Saharan Atlas) and only 5.7% (12 taxa) for the northern and central Saharan region. For 10.4% (22 taxa) of alien plants there is no information available on their distribution in Algeria. Lastly, we must add that 7.6% (16 taxa) of alien plants are widespread and present everywhere in Algeria (Figure 6), from the littoral area to the central Sahara, namely *Ricinus communis* L., *Oxalis pes-caprae* L., *Agave americana* L., *Opuntia ficus-indica* (L.) Mill., *Erigeron* spp., *Xanthium* spp., *Nicotiana glauca* Graham, *Ailanthus altissima* (Mill.) Swingle, *Amaranthus* spp., etc. Conversely, 40% of alien species (85 plants) are now present in only one region in Algeria, with 43 plants in Algiers region, 16 plants in Oran region and 10 plants in Annaba-El Kala region.

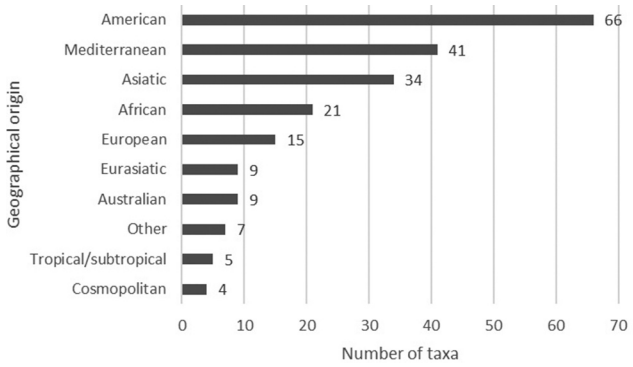

Figure 4. Regions of origin for the alien flora of Algeria.

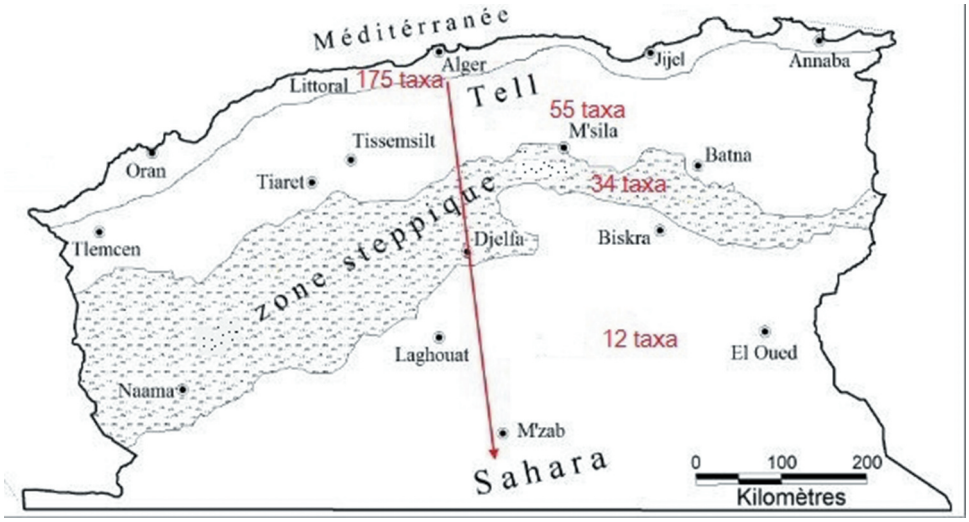

Figure 5. Number of alien plants per natural zone and the reduction of their relative frequency in Algeria according to a North-South geographic gradient.

Types of habitat colonized

Of the 211 alien plants identified in this analysis, it appears that (Figure 7):

- 44.5% are only established in anthropogenic habitats (crops, orchards, gardens, oases) and 17.5% in ruderal habitats (rubble, vacant lots, roads, roadsides and railways). These species can be classified as epoecophytes according to Kornas (1990);
- 15.2% have been able to colonize semi-natural habitats (beaches and back-dunes, wastelands, hedgerows, rocks) which are often subject to some human and/or livestock pressure (trampling, eutrophication, etc.); these species fall into the category of hemiagriophytes (Kornas 1990).
- 11.8% managed to establish in habitats with natural vegetation (wetlands, streams, meadows) and could be classified as holoagriophytes *sensu* Kornas (1990).

Alien plants occupy a wide range of artificial, semi-natural and natural habitats in Algeria. However, the vast majority of alien plants, i.e. 62% in total, have colonized anthropogenic habitats, such as ruderal environments and fields in agricultural and urban landscapes.

Introduction pathways

Alien plants have been introduced either deliberately or unintentionally in Algeria. A high rate (61.6 %) of alien plants have been introduced deliberately for ornamental purposes (gardens, hedges, roadsides; 43.6%) and for other uses (food, fodder, timber, fibers, etc.; 18%). Plants introduced unintentionally represent a percentage of 38.4%; they are usually mixed with the seeds of other species (contaminants) and/or hitchhikers on transport vectors (Hulme et al. 2008).

Invasive or potentially invasive alien plants

In Algeria, 34 taxa (16.1%, n = 211) of naturalized alien plants are actual (19 taxa) or potential (15 taxa) invasive plants (Table 2). They fulfil the criteria to be characterized as invasive (after Richardson et al. 2000; Pyšek et al. 2004), based on our *in situ* observations and the current knowledge in the field and taking into account their distribution across the Algerian natural regions, and the types of habitats colonized. They are classified according to their degree of invasiveness in three classes (after Sanz Elorza et al. 2001; Dana et al. 2001).

These invasive plant species represent a real or potential threat to native flora in semi-natural and natural habitats, especially those with high local or regional spread, belonging to the classes 3 or 2 of invasivenes: *Acacia mearnsii* De Wild., *Ailanthus altissima* (Mill.) Swingle, *Carpobrotus edulis* (L.) NE Br., *Cotula coronopifolia* L., *Nicotiana glauca* Graham, *Opuntia ficus-indica* (L.) Mill., *Paspalum distichum* L., *Phytolacca americana* L., *Ricinus communis* L., *Robinia pseudoacacia* L., *Xanthium* spp., etc. Other invasive species (jnvasiveness class 3), such as *Oxalis pes-caprae* L., *Cuscuta campestris* Yunk. and *Solanum elaeagnifolium* Cav. are considered as serious threat to agriculture infesting crops over large areas in Algeria.

Discussion

The alien flora of Algeria comprises at least 211 taxa (species and subspecies). This preliminary checklist of the alien flora of Algeria provides a greater number than previous studies. According to Ducellier and Maire (1923), introduced plants were relatively few in North Africa, with a list of 163 species (almost all observed in Algeria). Vilà et al. (1999) give 343 alien plants present in North Africa, including 143 species

Figure 6. Most common naturalized alien plants in Algeria, most of them are invasive. A. *Erigeron canadensis* L., forêt de Tamgout, Tizi Ouzou; 30.11.2014. B. *Leucaena leucocephala* subsp. *glabrata* (Rose) Zárate, forêt de Kissir, siège du parc national de Taza, Jijel; 12.06.2019. C. *Opuntia ficus-indica* (L.) Mill., gorges du Ghoufi, Aurès, Batna; 29.11.2018. D. *Acacia karroo* Hayne, embouchure de l'oued Chlef, Mostaganem; 25.07.2018.E. *Ailanthus altissima* (Mill.) Swingle, djebel Yemma Gouraya, parc national de Gouraya, Béjaia; 21.08.2016. F. *Nicotiana glauca* Graham, dunes du Cap Falcon, Oran; 15.08.2013.G. *Agave americana* L., djebel Murdjadjo, Oran; 26.07.2018. H. *Xanthium orientale* subsp. *italicum* (Moretti) Greuter, lit de l'oued Aissi, Tizi Ouzou; 24.08.2013. I. *Oxalis pes-caprae* L., littoral de Corso, Boumerdès; 05.03.2013. J. *Ricinus communis* L., littoral de Dellys, Boumerdès; 04.11.2013. All photos: R. Meddour.

in Algeria. The recent and more comprehensive work of Chatelain in Dobignard and Chatelain (2010–2013) gives a rate of introduced plants (naturalized and casual) of 3.4% for Algeria (c. 152 taxa), versus 3.2% for Morocco (which includes 141 casual and naturalized species, according to Fennane and Ibn Tattou 2012) and 2.43% for Tunisia (which includes 92 alien plant taxa, after Sayari and Mekki 2016). This makes Algeria one of the North African countries with the greatest diversity of alien plants. This proportion

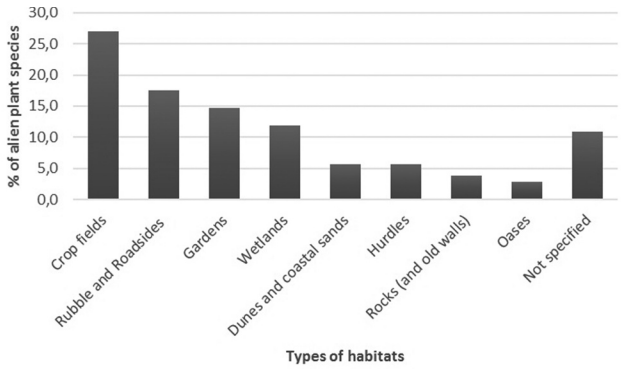

Figure 7. Percentage of alien plants according to the types of habitats in Algeria.

Table 2. Hierarchical list of alien plant species considered invasive or potentially invasive in Algeria.

Invasive or potentially invasive alien plant species in Algeria	Invasiveness class	Invasive or most widespread in other regions	References
Invasive plant species			
Acacia mearnsii De Wild	3	World	10
Acacia saligna (Labill.) H.L. Wendl.	3	North Africa	1
Ailanthus altissima (Mill.) Swingle	3	Algeria, North Africa, Mediterranean region, Mediterranean France, Mediterranean islands, Europe, World	1, 2, 3, 4, 5, 6, 7, 8, 10
Polygala myrtifolia L. var. *myrtifolia*	3	World	10
Robinia pseudoacacia L.	3	North Africa, Mediterranean region, Mediterranean France, Europe, World	1, 3, 4, 5, 8, 10
Carpobrotus edulis (L.) N.E. Br.	3	North Africa, Mediterranean region, Mediterranean islands, Mediterranean France, World	1, 3, 4, 7, 8, 10
Opuntia ficus-indica (L.) Mill.	3	Mediterranean region, Mediterranean islands, World	3, 4, 7, 10
Cotula coronopifolia L.	3	World	10
Oxalis pes-caprae L.	3	Algeria, North Africa, Mediterranean islands, Mediterranean France, World	2, 4, 6, 7, 8, 10
Phytolacca americana L.	3	Algeria, Europe, World	5, 6, 10
Solanum elaeagnifolium Cav.	3	North Africa, Mediterranean France	2, 8, 9
Cuscuta campestris Yunck.	3	Europe	5
Paspalum distichum L.	3	Mediterranean France, Europe, World	4, 5, 8, 10
Ricinus communis L.	2	Algeria, North Africa, Europe, World	1, 2, 5, 6, 10
Nicotiana glauca Graham	2	North Africa, Mediterranean islands, World	1, 2, 7, 10
Xanthium strumarium L. subsp. *strumarium*	2	Europe, World	5, 10
Erigeron bonariensis L.	2	North Africa, Mediterranean islands, Europe	1, 2, 5, 7
Erigeron canadensis L.	2	Mediterranean islands, Europe	5, 7
Symphyotrichum squamatum (Spreng.) G.L. Nesom	2	North Africa, Mediterranean islands	2, 7
Potentially invasive plant species			
Leucaena leucocephala subsp. *glabrata* (Rose) Zárate	2	World	10
Ipomoea indica (Burm.) Merr.	2	World	10
Polygonum baldschuanicum Regel	2	Europe	5
Agave americana L.	2	Mediterranean islands, Mediterranean France, World	7, 8, 10
Carpobrotus acinaciformis (L.) Bolus	2	Mediterranean region, Mediterranean France	3, 8
Ageratina adenophora (Spreng.) R.M. King & H. Rob.	2	North Africa, World	1, 10
Ambrosia artemisiifolia L.	2	Mediterranean region, Mediterranean France, Europe, World	3, 4, 5, 8, 9, 10
Xanthium spinosum L.	2	North Africa, Mediterranean islands, Europe, World	1, 2, 5, 7, 10
Acacia melanoxylon R. Br.	1	North Africa, World	1, 10
Elaeagnus angustifolia L.	1	North Africa, Mediterranean France, World	1, 8, 10
Lantana camara L.	1	Algeria, World	6, 10
Abutilon theophrasti Medik.	1	Europe	5
Chenopodium ambrosioides L.	1	Mediterranean islands, Europe	5, 7
Erigeron karvinskianus DC.	1	World	10
Xanthium orientale subsp. *italicum* (Moretti) Greuter	1	North Africa	1

Invasiveness classes (after Sanz Elorza et al. 2001; Dana et al. 2001):
3 = dangerous (causing ecological damage or alteration) for natural ecosystems,
2 = it is known as invasive and although it is not threatening natural or man-made ecosystems, it is suspected to do it in the near future,
1 = with a clear invasive behavior, although by the moment it is only found in largely disturbed systems. It is needed to monitor its further behavior.
References: 1. "Naturalized plants of northern Africa which are also invasive elsewhere" (Vilà et al. 1999). 2. "Native or introduced plant taxa undergoing a strong expansion in Northern Africa" (Le Floc'h et al. 1990). 3. « Plantes envahissantes de la région méditerranéenne » (Brunel 2003). 4. « 100 of the world's worst invasive Alien Species », GISD, Global invasive species 2014–2020 database (http://www.iucngisd.org/gisd/100_worst.php). 5. "The 150 most widespread alien plant species in Europe" (Lambdon et al. 2008). 6. « Les espèces envahissantes en Algérie », http://www.bionet-nafrinet.net/algeria.html (Zeddam 2008). 7. "The top 10 alien species on Mediterranean islands" (Hulme et al. 2008). 8. « Major and emerging invaders in continental Mediterranean France » (Brunel et Tison 2005). 9. "Emerging invasive alien species in the Mediterranean Basin" (Brunel et al. 2010). 10. "Invasive plant species of the world" (Weber 2017).

being actually higher according to our data: 4.7% of overall vascular flora of Algeria, which has 4 449 taxa (species and subspecies) according to Dobignard and Chatelain (2010–2013).

In the Northern Mediterranean region, this proportion of alien plants in floras usually exceeds 10%. For example, the rate of alien species account for 13 to 13.5% of the total flora of Spain (Vilà et al. 2001; Sanz Elorza et al. 2004), 15 to 17.9% of the flora of Portugal (Almeida and Freitas 2001, 2012), and 13.4 to 19.5% of the Italian flora (Celesti-Grapow et al. 2011; Galasso et al. 2018). Nevertheless, the overall percentage of alien species in Turkey accounts for only 1.5 to 2.8% of the flora (Ugurlu and Crosti 2010; Arslan et al. 2015; Uludağ et al. 2017), and 5% of the flora in Greece (Arianoutsou et al. 2010). These rates are closer to those of Maghreb countries.

We found that out of the 211 alien taxa recorded in the wild in Algeria, 51% were naturalized and 36% were classified as casual (184 taxa in all). The rate of naturalized species among alien species in Algeria appears noticeably high. On the one hand, this may indicate that many casual species are lacking in this preliminary checklist. Historical casual species may have not been recorded, as the interest on alien flora is recent in North Africa. On the other hand, our results agree well with data from Greece, where a high percentage of alien plant species (c. 40%) are naturalized (Bazos et al. 2009), as well as in Turkey, where 68% of alien species are considered naturalized while only 32% are casual (Uludağ et al. 2017). Finally, our study identified for the first time among naturalized species, a list of 34 invasive or potentially invasive species in Algeria. This latter category represents 33% of naturalized species which is again a high rate compared to the expectations of the tens rule hypothesis (Jeschke et al. 2012). However, when this number is compared to the total number of species introduced (and found in the wild), this rate (16.1%) is similar to some countries or regions of Mediterranean basin. For example, in the province of Napoli (Italy), Motti and Stinca (2008) identified 17.4 % of invasive plants, and in Corsica, according to Jeanmonod and Natali (1997), this rate is of 14.2%.

A detailed classification of alien plants of Algeria based on the degree of naturalization is still difficult, because of the lack of resources for the monitoring of alien plants in the field, resulting in limited information available on the ecological behavior and the spread of many species. There is a need for more investigation, especially on the naturalization of trees and shrubs (Richardson and Rejmánek 2011).

Alien plants in Algeria belong mainly to angiosperms/eudicots (185 taxa), followed by monocotyledons by far (25 species), while gymnosperms are recorded with only one species. This assessment is relatively close to that of Vilà et al. (1999), who note that the systematic composition of the naturalized flora in Algeria is as follows: "dicotyledons" (107 taxa), monocotyledons (18) and gymnosperms (2). Furthermore, in North Africa (Vilà et al. 1999), as in Central Italy (Ballelli and Pedrotti 2009) or in Spain (Vilà et al. 2001; Campos et al. 2004) and Portugal (Almeida and Freitas 2001, 2012), the same large families (*Asteraceae, Fabaceae, Brassicaceae*, . . .) dominate the alien flora. However, some of the large species-rich families are under-represented, especially *Poaceae*. For some families (e.g. *Apiaceae, Caryophyllaceae*), this under-representation may be explained by a lack of trait values conferring invasiveness (Pyšek 1998; Pyšek et al. 2017). However, for the *Poaceae* family, we suspect that their under-representation may be due to a bias in detection effort. We therefore encourage botanists to take an interest in exotic grasses, of which many ornamental species planted in beds are likely to become naturalized (D'Antonio and Vitousek 1992).

Most of the alien plants come from the Americas, with more than 31% of all taxa. Le Floc'h et al. (1990) already indicate the predominance of American origin (45%) of plants introduced in North Africa. According to Kazi Tani (2012), the majority of alien species (40%) recorded in different croplands of western Algeria come from the American continent. This is a well-established pattern in the whole Mediterranean Region (Jeanmonod and Natali 1997; Vilà et al. 2001; Almeida and Freitas 2001; Campos et al. 2004; Verloove and Sánchez Gullón 2008; Ballelli and Pedrotti 2009; Stešević and Petrović 2010). Other regions in the Mediterranean Basin represented the second highest origin of alien species of Algeria. This is not surprising, as the closest regions generally have closer economic ties and therefore a greater flow of imports of goods (including plants). Similarly, Lambdon et al. (2008) showed that alien flora in European countries were mainly introduced from other regions of Europe. Moreover, this close geographic origin may explain their success in naturalization due to similar climates in the area of origin (Le Floc'h et al. 1990). In this regard, plants from South Africa are few in number (8%), but they show outstanding adaptability, naturalization and even invasion, such as *Oxalis pes-caprae* L., *Carpobrotus edulis* (L.) NE Br., *Cotula coronopifolia* L., *Acacia karroo* Hayne, etc. This may be due again to a similar Mediterranean climate in their area of origin.

Therophytes largely predominate in Algerian alien flora (43%). This result is consistent with the biological spectrum of alien plants in the whole North Africa that shows that 45–46% of plants are therophytes (Le Floc'h et al. 1990; Vilà et al. 1999). Similar rates have been recorded in Spain, with 41% of therophytes (Vilà et al. 2001) and in Portugal, where this proportion is 35% (Almeida and Freitas 2001). Annuals are the predominant growth form among the species present, as they are best suited to disturbed habitats, such as urban and suburban areas, cultivated lands, wastelands and ruderal areas (Ballelli and Pedrotti 2009). The ability to produce

many seeds, more or less dormant, also makes it easy for annual species to contaminate seed lots of cultivated species or to be accidentally associated with other commodities. The prevalence of annuals may also reflect the identity of introduced plants, e.g. *Amaranthaceae* and *Poaceae* contain many weeds of agroecosystems (Vilà et al. 1999). On the other hand, we found a relatively important proportion of woody plants (22% of phanerophytes, nanophanerophytes and chamaephytes/trees, shrubs, woody climbers) in the alien flora of Algeria, as well as that of the whole of North Africa (Le Floc'h et al. 1990; Vilà et al. 1999).

In relation to the dominance of therophytes, a large amount of alien plants has colonized anthropogenic habitats (62%), as observed elsewhere (Jeanmonod and Natali 1997; Küzmič and Šilc 2017). For example, in Spain, according to Vilà et al. (2001), the vast majority of naturalized plants are found in ruderal environments and arable fields. These human-made habitats are also those that facilitate the most their spread in our case, as elsewhere in the Mediterranean region (Hulme et al. 2008). It is known that introduced species, mostly therophytes, concentrate in disturbed habitats, colonize ruderal environments or infest crops, because of their pioneering nature. They are favored by disturbances and fragmentation of habitats (Campos et al. 2004). This is explained by the fact that most of these introduced plants have a life strategy termed "r-selected traits" by Pianka (1970 in Castro-Diez et al. 2014), so they allocate a large proportion of their energy to the production of diaspores: *Xanthium, Erigeron/Conyza, Heliotropium, Atriplex, Amaranthus*, etc. (Le Floc'h et al. 1990). The relationship between the success of naturalization and disturbance has already been noted for plants (Hobbs and Huenneke 1992). This can be seen in this study because the number of alien plants according to the types of habitats increases rendering to their degree of artificialization. Besides, the establishment of alien plants in natural habitats, as here wetlands, is relatively least important (11.8%). However, these "natural" riparian environments are not exempt from a low level of anthropogenic disturbance in Algeria. Indeed, linked to disturbances modifying local conditions (opening of the canopy, drying of the substrate), several alien species (*Oxalis aticulata* Savigny, *Paspalum distichum* L., *Phytolacca americana* L., *Ricinus communis* L.) are naturalized in the alder groves in north-east Algeria (Belouahem-Abed et al. 2011).

In Algeria, a high proportion of alien plants have been introduced deliberately for ornamental purposes (61.6 %). This is also true for all of North Africa (Le Floc'h et al. 1990; Le Houérou 1995). The deliberate introduction of alien plants for ornamental horticulture is considered as the most important pathway for plant invasions around the world (Kowarik 2005; Hulme et al. 2008). Regional analyses of alien naturalized floras have shown that usually more than 50% of these species were introduced for ornamental horticulture purposes (van Kleunen et al. 2018b).

If the species introduced, deliberately or accidentally, and now completely naturalized, represent a floristic enrichment for a territory, some of them, considered invasive (Di Castri 1990; Lambinon 2005; Cronk and Fuller 2014), by proliferating in the natural environments can produce serious nuisances (loss of biodiversity, deep modification of the ecosystems) (Brunel 2003; Muller 2004; Paradis et al. 2008). We can mention the typical case of *Ailanthus altissima* (Mill.) Swingle and *Robinia pseudoacacia* L., known for their high speed of propagation (Lefeuvre 2006; Castro-Diez et al. 2014), which is confirmed in Algeria in some protected areas (National parks of Chréa and Gouraya). Another representative case and in addition in natural habitat is that of *Acacia mearnsii* De Wild., introduced in 1970 in the National Park of El Kala (North-East of Algeria) (Boudiaf et al. 2014). This alien species, with very high invasive potential (Richardson and Rejmánek 2011), has invaded this national park, establishing dense stands, which are gradually supplanting that of the cork oak (*Quercus suber* L.) and associated native flora (Boudiaf et al. 2014). This is also the case of *Oxalis pes-caprae* L., *Cuscuta campestris* Yunk., *Solanum elaeagnifolium* Cav. and *Bassia scoparia* (L.) A.J. Scott, which infest crops locally or over large areas in Algeria (Zermane and Saghir 1995; Rahim et al. 2001; EPPO 2006, 2007, 2010; Benmeddour and Fenni 2008; Kazi Tani 2014; Adjim and Kazi Tani 2018; Hamel and Azouz 2018). We can also cite the case of *Cotula coronopifolia* L., reported with doubt more than a century ago in Algeria (Battandier and Trabut 1888–1890), which reached a considerable extension in the lakes of El Kala (Belouahem-Abed et al. 2011; Hamel and Azouz 2018), where this alien species takes the place of native plants. This species has invaded a large part of coastal wetlands and brackish marshes in Corsica in only 30 years (Jeanmonod and Natali 1997; Jeanmonod 1998).

All these alien plants were already reported on the lists of invasive alien species established especially for the Mediterranean region, but also for other regions of the world (see Brunel 2003; Brunel and Tison 2005; Hulme et al. 2008; Lambdon et al. 2008; Brunel et al. 2010; Weber 2017). However, for many naturalized species in Algeria, we lack data and *in situ* observations in all the vast Algerian territory to give a precise invasion status accounting for their current dynamic. In addition, a number of alien plants are too recent introduction (less than 10–20 years), so that we can decide if they present a real risk or no. It is the case of recent introductions, for example: *Oenothera rosea*

L'Hér. ex Aiton, *Physalis acutifolia* (Miers) Sandw., *Senecio angulatus* L.f., *Gnaphalium antillanum* Urb. (Hamel 2016; Rebbas 2018; Miara et al. 2018; Hamel and Azouz 2018).

When comparing our data with those available for Algeria (DZA, code 321) in the recent GloNAF database (van Kleunen et al. 2018a), it appears that 227 taxa are considered as naturalized in Algeria. From this total, we found that 96 taxa in the GloNAF database are also listed in our contribution. Several reasons can afford for the differences between GloNAF and our present work. First, 34 taxa listed in GloNAF are simply duplicates and must be removed from this list. Second, for 42 taxa, a native status in Algeria has been established for a long time, for example *Ammi majus* L., *Astragalus boeticus* L., *A. caprinus* L., *Bromus rubens* L., *Calendula arvensis* M.Bieb., *Calotropis procera* (Aiton) Dryand., *Glebionis coronaria* (L.) Cass. ex Spach, *Cichorium intybus* L., *Erodium battandieranum* Rouy, *Euphorbia helioscopia* L., *Lotus corniculatus* L., *Myrtus communis* L., *Reseda luteola* L., *Papaver hybridum* L., *Trifolium campestre* Schreb., *Urtica urens* L., *Veronica arvensis* L., *Vicia villosa* Roth, etc. Finally, only 55 taxa, given as naturalized in GloNAF, remain to be considered in a forthcoming contribution updating the present preliminary checklist. In fact, according to APD and E+M database, the taxa worthy of interest cited in GloNAF are merely 28 naturalized or casual alien, such as *Amaranthus spp., Datura spp., Opuntia spp, Anredera cordifolia* (Ten.) Steenis, *Iris germanica* L., *Morus alba* L., *Trifolium alexandrinum* L., *T. incarnatum* L., *Veronica persica* Poir., etc. The others either are only cultivated or needs further investigations to determine their precise status.

Conclusion

This research provides a preliminary checklist of alien vascular plants in Algeria, the largest country in Africa and the 10th largest country in the world. This is one of the first national lists for a North African country representing a comprehensive compilation and analysis of all available records on alien plants in Algeria, and providing an assessment of their traits and status in this understudied region, for which basic data on the alien flora is still often lacking. There are nowadays at least 211 alien plants in the country, of which 108 are naturalized, according to the available information. We have provided a hierarchical list of 34 plant species that are considered more or less invasive, as a first step. However, most alien plants invade artificial habitats, keeping the natural ones relatively intact.

This study has identified knowledge gaps, such as the exact geographic distribution of some alien species in Algeria, their degree of naturalization and the quantification of the ecological and economic impacts of alien plants. Among the improvements to this preliminary checklist, we will assess and integrate relevant data from recently available international databases (GloNAF (glonaf.org), GRIIS (www.griis.org)), compile more broadly the data from the herbaria, specify as far as possible the dates of introduction or first mention in Algeria and detail the distribution patterns of the species. With the present study, our intention is to make a "zero state" to allow future monitoring of alien plants, but also to draw attention to the problems that the expansion of invasive plants may cause. Nevertheless, precise spatial information about their distribution is still lacking and the situation is changing rapidly over the time. It is therefore a long-lasting inventory of the current and potentially invasive plant situation that needs to be realized. On the other hand, regional floristic in-depth knowledge must be led by an increase in field-orientated surveys, on this subject in Algeria, in order to remove a large part of the uncertainties concerning some of the alien plants (introduced species that are insufficiently documented and not evaluated). Large-scale inventories, impact assessment and prioritization are requirements for shortening the spread of these alien plants.

Authors' contributions

Rachid Meddour contributed in the research conception, acquisition of data, analysis and interpretation, and reviewed the final draft. ***Ouahiba Sahar*** drafted some of the sections, contributing particularly to the section of checklist and number of alien plant species and reviewed the final draft. ***Guillaume Fried*** contributed to the section of types of habitat colonized, coordinated the team during the writing of the manuscript, provided additions and comments, and revised the final draft.

Acknowledgments

We thank Tarek Hamel (Badji Mokhtar University of Annaba) for useful comments on a previous version of this manuscript.

Disclosure statement

We have no conflict of interest to declare.

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