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Analysis of the adventive flora of a Greek city: The example of Patras

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Abstract

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This paper analyses the adventive flora of the city of Patras, Western Greece. The origins, times and methods of introduction are analyzed, along with the city's spatial structure, human impact, habitat types, establishment and naturalization. Taxa of American origin dominate, as do neophytes, while ornamentals are the major source of adventive taxa, especially established ones. Inner city areas have a small number of adventive taxa which, nevertheless, form a significant percentage of their total flora, while suburban areas have lower percentages of adventives. The application of the hemeroby scale, showed a trend of adventives or neophytes, to increase proportionately with human disturbance. Very disturbed urban habitats, such as tree beds and pavements, had the highest percentages of adventives while in less disturbed non-urban habitats, percentages of adventives were very low. Compared with central European cities, Patras has low percentages of adventives and neophytes, the majority of which are epoecophytes, while agriophytes are lacking. This can be attributed to the resistance of the native Greek flora to invasions of new taxa due to its great stability and, moreover, the significant participation of apophytes in the synanthropic flora of Patras.

Key words: Urban ecology, adventives, hemeroby, Patras, Greece.

1. Introduction

Work on the adventive flora of Greece has been limited mainly to references in floristic studies or studies of particular species. A review of the adventive flora of Greece and a study of the adventive flora of Crete, were carried out by Yannitsaros (1982, 1991).

The present study is the second in a series carried out by the authors as part of a research project on the urban ecology of Greece. The adventive flora of a Greek city, relative to origin, time and method of introduction, the city's spatial structure, habitat types, human impact, and establishment status and naturalization, is studied here in its entirety for the first time.

The city of Patras lies in a plain on the NW coast of Peloponnisos (Fig. 1). The study area includes the whole metropolitan area of Patras, which is of average size and population by Greek standards, covering an area of ca. 58 km^2 with a population of ca. 170,000 inhabitants (1991 census data). This study is supported by a parallel one concentrating on the extensive registration of the flora of Patras (Chronopoulos and Christodoulakis 1996).

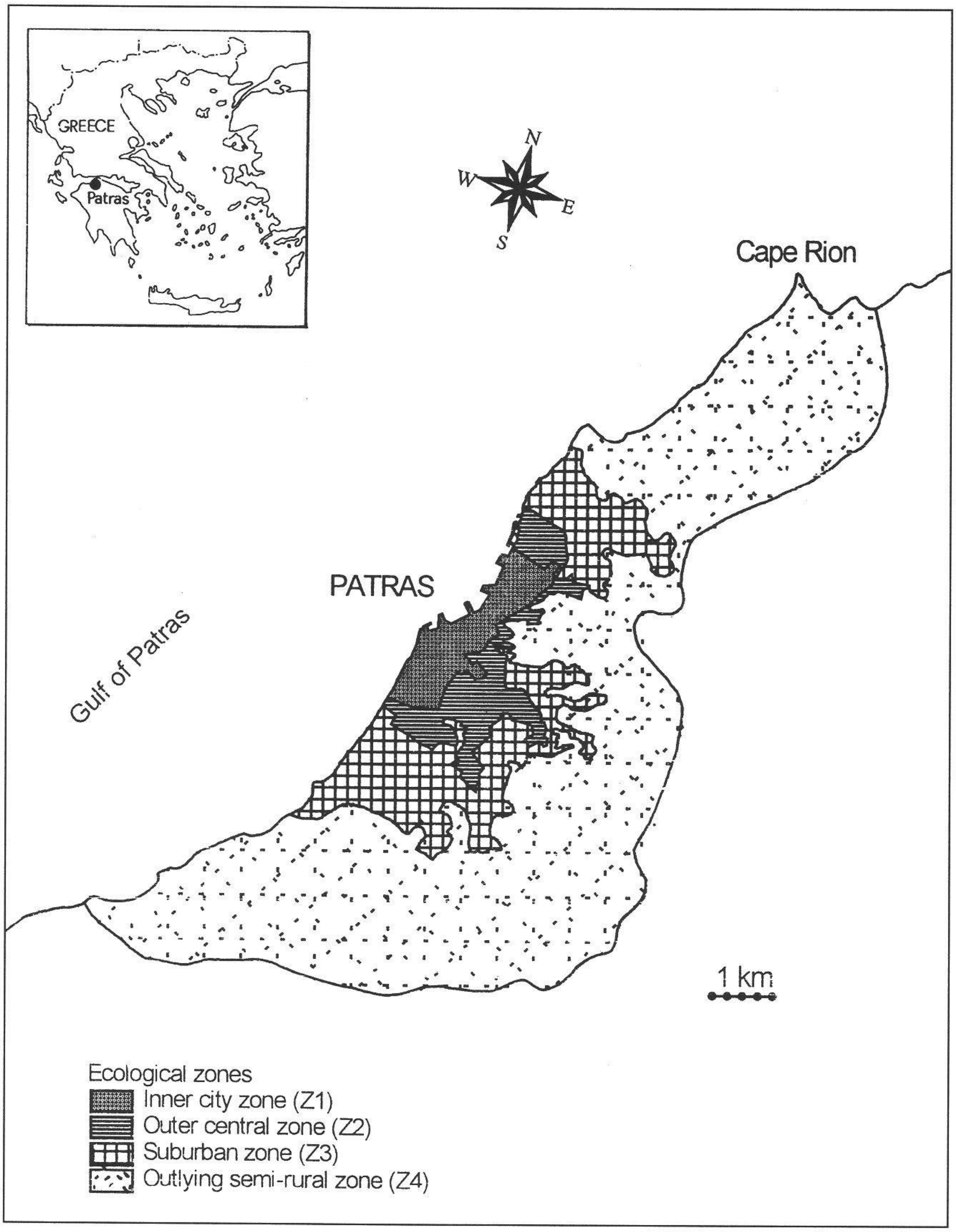

Fig. 1. Map of Patras showing the four ecological zones identified

2. Materials and methods

Following Wittig et al. (1993), the metropolitan area of Patras was divided into the following four ecological zones, according to city planning and land use types: inner city zone (Z_1), outer central zone (Z_2), suburban zone (Z_3), and the outlying semi-rural zone (Z_4), (Table 1, Fig. 1). Twenty-two, representative habitat types were also distinguished (Table 2).

Table 1. Ecological zones of the city of Patras and their general characteristics

Ecological zone	Description
Inner city zone (Z1)	Expansion between 1858 and 1971, very high degree of ground sealing (~90%), six storeyed buildings (70%) and listed houses of 1–2 storeys (30%), densely populated, mixed uses (residential, administrative, commercial, cultural, social infrastructure, traffic, and transportation).
Outer central zone (incl. old city) (Z2)	Expansion until 1858 (old city) and between 1971 and 1975 (newer part), high degree of ground sealing (~80%), 1–2 storeyed (50%, mostly listed houses in the old city) and 3-6 storeyed buildings (50%), densely populated, residential use.
Suburban zone (Z3)	Expansion between 1971 and 1989, degree of ground sealing ~60%, 3-6 storeyed (30%) and 1–2 storeyed buildings (70%), sparsely populated, residential use, athletic infrastructure, gradual abandonment of agricultural land.
Outlying semi-rural zone (Z4)	Recent, generally sparse buildings for first and second residential use mixed with clusters of old settlements, low degree of ground sealing ~25%, 0–2 storeyed (90%) and >2 storeyed buildings (10%), sparsely populated, recreational, academic and athletic infrastructure, transportation, agriculture, relics of natural landscape.

The flora of Patras was registered mostly from 1993 to 1995 (see also Chronopoulos and Christodoulakis 1996). In addition, 400 vegetation relevés of 1–100 m^2 were taken from all habitat types of each ecological zone, using the Braun-Blanquet method. To evaluate the sum effects of past and present human activities on current site conditions or the vegetation of each relevé, the hemeroby scale was used. This scale is used in Central Europe (see Kowarik 1990), and was adapted by the authors to correspond with environmental conditions of Greece/Mediterranean (Table 3).

Following Thellung (1915, 1918–19), Schröder (1969, 1974) and Sukopp (pers. com.), all taxa recorded were categorized into synanthropic and non-synanthropic taxa, according to their relation with humans. Two important groups were distinguished in the synanthropic category: apophytes, i.e. native taxa which have been removed from their primary, natural and semi-natural habitats to secondary, man-made ones (Thellung 1918–19), and adventives. In this paper, adventive taxa are defined as alien plants, introduced unintentionally by man, and escapes from cultivation (ergasiophygophytes) that thrive spontaneously or sub-spontaneously in Patras area.

Data on the origins of adventives were taken mainly from Tutin et al. (1964–1980) and Pignatti (1982), and also Davis (1965–1985), Garcke (1972), and Oberdorfer (1979). Data on archaeophytes (adventives introduced before 1500 AD) in Greece, were taken from Hort (1961), Lenz (1966) and Baumann (1982).

To estimate the present, local, establishment status of each adventive taxon, three categories of adventives were distinguished: Established (E), doubtfully established (D), and cas-

Table 2. Numbers and proportions of neophytic and archaeophytic adventives for each habitat type of Patras in relation to the degree of human impact

	Habitat type	Human impact	Amplitude of human impact per habitat type according to the hemeroby scale	Arithmetic mean hemeroby value	Total number of taxa per habitat	Adventives: Neophytes No.	Neophytes %	Archaeo-phytes No.	Archaeo-phytes %	Total %
1	Tree beds		H8–9	8.8	91	21	23.1	1	1.1	24.2
2	Pavements		H8–9	8.5	122	23	18.9	2	1.6	20.5
3	Wastelands Z1*		H6–9	8.2	172	25	14.5	7	4.1	18.6
4	Stone-paved areas		H8	8.0	48	6	12.5	1	2.1	14.6
5	Coastal wastelands	High	H6–9	8.0	195	11	5.6	6	3.1	8.7
6	Wastelands Z2*		H5–9	7.5	185	30	16.2	5	2.7	18.9
7	Planted green areas		H7–8	7.2	209	20	9.6	3	1.4	11.0
8	Disused industrial areas		H5–9	7.0	150	14	9.3	5	3.3	12.6
9	Roadsides		H5–9	6.9	303	44	14.5	8	2.6	17.1
10	Railway tracks		H4–9	6.5	335	28	8.3		1.8	10.1
11	Wastelands Z4*		H3–9	6.5	576	36	6.3	11	1.9	8.2
12	Fallow land		H5–8	6.3	329	25	7.6	10	3.0	10.6
13	Cemeteries		H4, 7–8	6.3	179	13	7.3	2	1.1	8.4
14	Wastelands Z3*	Medium	H4–9	6.2	357	39	10.9	8	2.2	13.1
15	Archaeological sites		H4–8	6.0	199	18	9.0	2	1.0	10.0
16	Walls		H4–7	5.1	88	6	6.8	2	2.3	9.1
17	Streams		H3–9	5.0	157	6	3.8	5	3.2	7.0
18	Seashores		H4–6, 9	4.8	47	1	2.1	–	0.0	2.1
19	Urban forests		H2–5	4.7	225	5	2.2	1	0.4	2.6
20	Wetlands		H2–4	3.4	67	3	4.5	3	4.5	9.0
21	Phrygana	Low	H2–4	3.4	278	2	0.7	1	0.4	1.1
22	Macchie		H2–4	3.0	180	2	1.1	–	0.0	1.1

H1–3: Low human impact
H4–6: Medium human impact
H7–9: High human impact

* Z1, 2, 3, 4 : see Table 1

uals (C) (Tables 4 & 5). These distinctions were made based on criteria of time and population biology. The time-criterion used was the report in Flora Europaea of each adventive taxon as "effectively naturalized, i.e. plant established in a single station for at least 25 years, or is reported as naturalized in a number of widely separated localities" (Tutin et al. 1964). Taking into account the age of the Flora europaea project (twenty years since the last volume was published), this was considered an adequate time criterion for the purposes of this study. The population biology criteria used relied on observations from the last six years. The three criteria are the dispersion of adventives in the different habitat types, their abundance, and their population's ability to propagate spontaneously from generation to generation (spontaneity) (see also Kowarik 1991). Each of the population biology criteria was fulfilled for an adven-

Table 3. Hemeroby scale with examples of vegetation and site types (based on Kowarik 1990) adapted to Greek/Mediterranean environmental conditions

Degree of hemeroby		Types of sites / vegetation
H0	ahemerobic	Only in some isolated site types of mainland and insular parts of Greece (e.g. cliffs).
H1	oligohemerobic	Virtually uninfluenced primary forests, growing flat or raised bogs, vegetation of rocks, river-banks, sea-shores and salt-marshes.
H2	oligo- to mesohemerobic	Forests with minor wood withdrawal or slightly grazed, primary forests near human-influenced sites, undisturbed macchie and phrygana vegetation, extensively drained wetlands, some wet meadows.
H3	mesohemerobic	More intensively managed forests, undisturbed developed secondary forests on man-made sites, degraded macchie vegetation, slightly disturbed phrygana, intensively managed wetlands, dry grasslands, traditionally managed meadows, undisturbed vegetation of old walls (e.g. some village walls, castles).
H4	meso- to β-euhemerobic	Monocultural forests, disturbed secondary forests, less ruderalized relics of various natural vegetation types, skirt vegetation, less ruderalized dry grasslands, slightly disturbed vegetation of old walls.
H5	β-euhemerobic	Young planted forests, intensively managed meadows and pastures, strongly ruderalized dry grassland on man-made sites, ruderal vegetation of shrubs or perennial tall herbs, more disturbed vegetation of old walls.
H6	β-eu- to α-euhemerobic	Traditionally managed field vegetation, trampled lawns, rough ruderal meadows, ruderal vegetation of annual herbs, more ruderalized vegetation of shrubs, strongly disturbed vegetation of urban old walls.
H7	α-euhemerobic	Intensively managed segetal, garden vegetation, very strongly disturbed wall vegetation (herbicide impact).
H8	α-euhemerobic to polyhemerobic	Segetal vegetation affected by strong herbicide impact (e.g. maize fields), ruderal pioneer vegetation, annual vegetation of heavily trampled ground.
H9	polyhemerobic	Pioneer vegetation on polluted sites (e.g railways, rubbish, dumps).
–	metahemerobic	No vegetation of vascular plants.

Table 4. Analysis of the adventive flora of Patras according to its establishment status

Status	Number of taxa	%
Established (E)	38	40.9
Doubtfully established (D)	10	10.7
Casuals (C)	45	48.4
Total	93	100

Table 5. Origin and establishment status of each adventive taxon in the area of Patras

Taxon	Origin	Establishment					Status & hemeroby amplitude of established taxa
		Time criterion	Population biology criteria				
		Taxon reported in Flora Europaea as naturalized in Greece (see text)	Dispersion		Abundance	Spontaneity	
			Number of habitats where the taxon is present	Occurrence in the total of 22 habitats (%)		Spontaneous propagation of populations from generation to generation	
• *Agave americana*	M	√	5	23	R → A	Successful	E (H4–5)
• *Ailanthus altissima*	Ch	√	11	48	R → A	Successful	E (H5–9)
• *Alcea setosa*	SWAs, Eg	–	3	14	VR	Unsuccessful	C
* *Allium cepa* ∇	WAs	–	3	14	VR	Unsuccessful	C
° *Amaranthus albus*	NA	√	5	23	R → A	Successful	E (H7–8)
° *A. blitoides*	NA	√	6	27	A	Successful	E (H7–9)
° *A. cruentus*	TA	√	12	55	A	Successful	E (H7–9)
◊ *A. deflexus*	SA	√	12	55	A	Successful	E (H7–9)
° *A. retroflexus*	NA	√	7	32	R → A	Successful	E (H7–9)
• *Antirrhinum majus* ∇	WMed	√	8	36	R → A	Successful	E (H5–9)
* *Arundo donax* ∇	CAs, SAs	√	8	36	A → VA	Successful	E (H3–9)
• *Asclepias curassavica*	TA	–	3	14	R	Unsuccessful	C
◊ *Aster squamatus*	CA, SA	√	16	73	R → VA	Successful	E (H5–9)
• *Bassia scoparia*	TeAs	√	6	27	R	Successful	E (H7–9)
◊ *Bidens pilosa*	SA	–	1	5	R → A	Successful	D
* *Brassica oleracea* ∇	WEur	–	1	5	VR	Unsuccessful	C
• *Calendula officinalis*	Med	–	3	14	R	Unsuccessful	C
• *Carpobrotus edulis*	SAf	√	4	18	R	Successful	E (H5–7)
◊ *Chenopodium ambrosioides*	TA	√	10	45	R → A	Successful	E (H7–9)
* *Cicer arietinum* ∇	CAs	–	2	9	VR	Unsuccessful	C
* *Citrullus lanatus* ∇	Af	–	4	18	VR → R	Unsuccessful	C
• *Commelina communis*	TeAs	–	3	14	VR	Unsuccessful	C
◊ *Conyza albida*	TA	–	17	77	R → VA	Successful	E (H5–9)
◊ *C. bonariensis*	TA	√	16	73	R → VA	Successful	E (H6–9)

Table 5. (Continued)

◊ *C. canadensis*	NA	√	9	40	VR → A	Successful	E (H7–9)
* *Coriandrum sativum* ∇	NAf, WAs	√	1	5	VR	Unsuccessful	C
◊ *Coronopus didymus*	SA	√	8	36	R → A	Successful	E (H6–9)
• *Cosmos bipinnatus*	NA	–	2	9	R	Unsuccessful	C
* *Cucurbita pepo*	NCA	–	2	9	VR	Unsuccessful	C
◊ *Cuscuta campestris*	NA	√	5	23	R	Successful	E (H5, 8)
• *Cymbalaria muralis* subsp. *muralis*	SAl, WJu, It, Si	√	5	23	R → A	Successful	E (H4–9)
• *Cyperus alternifolius*	Af	–	3	14	VR → R	Unsuccessful	C
• *Datura innoxia*	CA	–	1	5	VR	Unsuccessful	C
◊ *D. stramonium*	M, ENA	√	7	32	R → A	Successful	E (H7–9)
≡ *Digitaria* cf. *ciliaris*	T, ST	–	2	9	R	Successful	D
° *Echinochloa colonum*	T, ST	–	1	5	R	Successful	D
• *Elaeagnus angustifolia*	TeAs	√	4	18	R	Unsuccessful	C
≡ *Eleusine indica*	T, ST	–	5	23	A	Successful	E (H7–9)
≡ *Eragrostis curvula*	SAf	–	1	5	R	Unsuccessful	C
• *Eschscholzia californica*	SWNA	–	1	5	R	Unsuccessful	C
◊ *Euphorbia prostrata*	NA	√	7	32	R → A	Successful	E (H4, 8–9)
* *Helianthus annuus*	NA	√	2	9	VR	Unsuccessful	C
• *H. tuberosus*	ENA	–	2	9	R	Unsuccessful	C
* *Hordeum distichon* ∇	SWAs, CAs	–	2	9	VR → R	Unsuccessful	C
* *H. vulgare* ∇	SWAs, CAs	–	3	14	VR → R	Unsuccessful	C
• *Ipomoea indica*	T	–	7	32	R → A	Successful	E (H5–9)
• *I. purpurea*	TA	√	4	18	VR → R	Successful	E (H7–8)
• *Iris albicans*	SAr ?	–	1	5	R	Unsuccessful	C
• *Lantana camara*	T, TeA	–	5	23	R	Unsuccessful	C
• *Lathyrus odoratus* ∇	SIt	–	1	5	VR	Unsuccessful	C
* *Lens culinaris* ∇	H, SWAs	√	2	9	VR	Unsuccessful	C
* *Lepidium sativum* subsp. *sativum* ∇	WAs, Eg	–	2	9	VR	Unsuccessful	C
* *Linum usitatissimum* ∇	Eur, WAs	–	1	5	VR	Unsuccessful	C
• *Lippia canescens*	SA	–	4	18	VR	Successful	D
• *Lobularia maritima*	CIs, Az	√	2	9	R → A	Successful	E (H7–9)
• *Lonicera japonica*	EAs	–	4	18	R	Successful	D
* *Lycopersicon esculentum*	CA, SA	–	6	27	VR	Unsuccessful	C

Table 5. (Continued)

Taxon	Origin	Establishment						Status & hemeroby amplitude of established taxa
		Time criterion	Population biology criteria					
		Taxon reported in Flora Europaea as naturalized in Greece (see text)	Dispersion: Number of habitats where the taxon is present	Dispersion: Occurrence in the total of 22 habitats (%)	Abundance	Spontaneity: Spontaneous propagation of populations from generation to generation		
◊ *Medicago sativa* subsp. *microcarpa*	CAs, SWAs	–	2	9	R	Unsuccessful		C
• *Melia azedarach*	In, Ch	–	9	40	R	Unsuccessful		C
• *Mirabilis jalapa*	TA	√	12	55	R → A	Successful		E (H6–9)
• *Morus alba* ∇	In, Ch	√	10	45	R	Unsuccessful		C
• *Nicotiana glauca*	SA	√	5	23	R → A	Successful		E (H7–9)
* *N. tabacum*	NEAr, Bo	√	1	5	VR	Unsuccessful		C
•· *Nothoscordum inodorum*	TeSA	–	3	14	R	Successful		D
• *Opuntia ficus-barbarica*	TA	√	4	18	VR → A	Successful		E (H4–7)
• *Oxalis articulata*	ETeSA	–	2	9	VR → R	Unsuccessful		C
• *O. debilis*	SA	–	3	14	VR → R	Successful		D
• *O. pes-caprae*	SAf	√	18	82	A → VA	Successful		E (H4–9)
• *Papaver somniferum* subsp. *somniferum* ∇	Med, SWAs?	–	3	14	VR → R	Unsuccessful		C
≡ *Paspalum dilatatum*	SA	–	5	23	A	Successful		E (H7–8)
≡ *P. paspalodes*	T	√	3	14	R → A	Successful		E (H7–8)
• *Passiflora caerulea*	CA, WSA	–	2	9	VR	Unsuccessful		C
• *Pennisetum villosum*	Eth	–	3	14	R	Successful		D
• *Persicaria capitata*	H	–	2	9	R	Successful		D
∨ *Phalaris canariensis*	CIs, NWAf	√	6	27	R	Successful		E (H3, 7–8)
° *Physalis cf. angulata*	TA	–	1	5	R	Unsuccessful		C
* *Raphanus sativus* ∇	SWAs ?	–	2	9	VR → R	Unsuccessful		C
• *Ricinus communis* ∇	T	√	5	23	R → A	Successful		E (H7–9)

Table 5. (Continued)

• *Robinia pseudoacacia*	NA	√	10	45	R	Successful	E (H4–8)
* *Sinapis alba* subsp. *alba* ∇	Med, WAs?	√	16	73	A → VA	Successful	E (H3–9)
◊ *Solanum elaeagnifolium*	TeSA	√	8	36	R → A	Successful	E (H6–9)
• *S. pseudocapsicum*	ESA	–	1	5	VR	Unsuccessful	C
* *S. tuberosum*	SA	–	4	18	VR	Unsuccessful	C
• *Teucrium fruticans*	WEur	–	3	14	VR	Unsuccessful	C
• *Tradescantia fluminensis*	SEBr, Ar	–	1	5	VR → R	Unsuccessful	C
* *Triticum durum* ∇	SWAs?	–	6	27	R	Unsuccessful	C
• *Tropaeolum majus*	Pe, Co	–	3	14	VR → R	Successful	D
° *Veronica persica*	SWAs	√	12	55	A → VA	Successful	E (H4–9)
* *Vitis vinifera* subsp. *vinifera* ∇	?	√	8	36	R	Unsuccessful	C
• *Wisteria sinensis*	EAs	–	6	27	VR	Unsuccessful	C
° *Xanthium spinosum*	SA	√	6	27	R → A	Successful	E (H7–9)
• *Zantedeschia aethiopica*	SAf	–	2	9	VR → R	Unsuccessful	C
**Zea mays*	T	√	3	14	VR	Unsuccessful	C

Key

Introduction method

*: agricultural plant (deliberately)
•: ornamental plant (deliberately)
v: bird fodder (deliberately)
°: weed of cultivation (inadvertently)
◊: traffic & trade (inadvertently)
≡: grass weed (inadvertently)

Time of introduction

∇: archaeophyte (before 1500 AD)
no symbol: neophyte (after 1500 AD)

Origin

Af: Africa
Ar: Argentina
Az: Azores
Bo: Bolivia
CA: C America
CAs: C Asia
Ch: China
CIs: Canary Islands
Co: Colombia
CSA: Central S America
EAs: E Asia
Eg: Egypt
ENA: Eastern N America
ESA: Eastern S America
ETeSA: Eastern Temperate S America
Eth: Ethiopia
Eur: Europe
H: Himalayas
In: India
It: Italy
M: Mexico
Med: Mediterranean
NA: N America
NAf: N Africa
NCA: Northern C America
NEAr: NE Argentina
NWAf: NW Africa
Pe: Peru
SA: S America
SAf: S Africa
SAl: S Alps
SAr: Saudi Arabia
SAs: S Asia
SEBr: SE Brazil
Si: Sicily
SIt: S Italy
ST: Subtropics
SWAs: SW Asia
SWNA: Southwestern N America
T: Tropics
TA: Tropical America
TAf: Tropical Africa
TAs: Tropical Asia
TeA: Temperate America
TeAs: Temperate Asia
TeSA: Temperate S America
WAs: W Asia
WEur: W Europe
WJu: W Yugoslavia
WMed: W Mediterranean
WSA: Western S America
?: Origin unknown
....?: Origin doubtful

Abundance:
A: Abundant = 11–50 Individuals per sampling habitat
R: Rare = 6–10 Individuals per sampling habitat
VA: Very abundant = >50 Individuals per sampling habitat
VR: Very rare = 1–5 Individuals per sampling habitat.

Status: see Table 4.

Hemeroby amplitude: see Table 3.

tive if : a) it was dispersed in five or more habitat types (occurrence >20%), b) it was at least rare in abundance, and c) it has successful spontaneity (Table 5).

Adventive taxa were considered "established" if they fulfilled at least three of the four criteria above, and one of these was criterion (c). Taxa that did not fulfil the time criterion but fulfilled all the other criteria, were considered "recently established". "Doubtfully established" taxa were those fulfilling at most two criteria, one of these being criterion (c). Finally, taxa which did not fulfil criterion (c) were considered "casuals".

The nomenclature used here follows Tutin et al. (1964–1980) and, where appropriate, Greuter et al. (1984–1989). The data was stored and processed using Dbase V.

3. Results

The number of wild, vascular taxa registered in the city of Patras was 816, ninety-three (11.4%) of which were adventives (Table 5). Over half of the adventives (49 taxa, 52.7%) belonged to the following six families: Gramineae (13 taxa, 14%), Compositae (10 taxa, 10.8%), Solanaceae (9 taxa, 9.7%), Leguminosae (6 taxa, 6.4%), Cruciferae (6 taxa, 6.4%) and Amaranthaceae (5 taxa, 5.4%). The remaining forty-four taxa (47.3%) belong to 31 families with one to three taxa each.

Tables 5 and 6 show that nearly half the adventive taxa were of American origin (44 taxa, 47.3%), and taxa of Asian (21 taxa, 22.6%), European-Mediterranean (8 taxa, 8.6%) and African (7 taxa, 7.5%) origin followed. Other areas of origin were represented by fewer taxa.

Most of the adventive taxa of Patras were neophytes (73 taxa, 78.5%), that is introduced after 1500 AD. Of these neophytes, American taxa dominated (44 taxa, 60.3%) and accounted for 8.9% of the city's total flora. In contrast, archaeophytes were much less common (20 taxa, 21.5%) and were mainly of Asiatic origin (10 taxa, 50%) (Table 6).

Table 7 shows that almost half the adventives were introduced into Patras as ornamentals (44 taxa, 47.3%), while a significant number was also introduced by agriculture (21 taxa, 22.6%). Taxa introduced by traffic and trade followed (14 taxa, 15%), and the remaining categories were less frequent.

The number of adventive taxa varied in different parts of the city according to the degree of urbanization. Thus, from the inner city zone to the outlying semi-rural zone, the total num-

Table 6. Origin of the adventive flora of Patras

Origin	Total number of adventives	%	Neophytes		Archaeophytes	
			Number	%	Number	%
America	44	47.3	44	60.3	–	–
Asia	21	22.6	11	15.1	10	50.0
Europe & Mediterranean region	8	8.6	5	6.8	3	15.0
Africa	7	7.5	6	8.2	1	5.0
Tropics & Subtropics	6	6.5	6	8.2	–	0.0
Asia & Africa	3	3.2	1	1.4	2	10.0
Europe & Asia	3	3.2	–	0.0	3	15.0
Unknown	1	1.1	–	0.0	1	5.0
Total	93		73		20	100

Table 7. Numbers and proportions of adventive taxa categorized according to their method of introduction, and their participation in each establishment state

Method of introduction	Number of adventives	%	Establishment state: Established Number	%	Doubtfully established Number	%	Casuals Number	%
Agricultural	21	22.6	2	5.3	–	0	19	42.3
Ornamental	44	47.3	15	39.5	6	60	23	51.1
Bird fodder	1	1.1	1	2.6	–	0	–	0
Weeds of cultivation	8	8.6	6	15.8	1	10	1	2.2
Traffic & Trade	14	15.0	11	28.9	2	20	1	2.2
Grass weed	5	5.4	3	7.9	1	10	1	2.2
Total	93	100	38	100	10	100	45	100

Table 8. Number and proportion of adventives for each ecological zone in Patras

Ecological zone	Total number of taxa	Adventives: Neophytes Number	%	Archaeophytes Number	%	Total Number	%
Inner city zone (Z1)	232	38	16.4	9	3.9	47	20.3
Outer central zone (Z2)	284	51	18.0	9	3.2	60	21.1
Suburban zone (Z3)	465	57	12.3	10	2.2	67	14.4
Outlying semi-rural zone (Z4)	751	55	7.3	14	1.9	69	9.2

ber of adventives increased from forty-seven to sixty-nine, while as a percentage of the total taxa of each zone, they decreased from 20.3 % to 9.2%. Similar trends were also seen in the neophytes (Table 8). Despite these general trends, the highest percentages of neophytes (18%) and total adventives (21.1%) were found in the outer central zone of the city (Table 8).

According to the arithmetic mean hemeroby value of the total samples from each habitat type (Table 2), it is concluded that the mean hemeroby value per habitat related to the total percentage of adventives (Fig. 2) and neophytes (Fig. 3) per habitat showed a good, positive linear correlation (R = 0.834 in both cases).

Tree beds, the open areas around city trees, had the highest mean hemeroby value (8.8), and accounted for the highest percentages of the adventive taxa (24.2%) and neophytes (23.1%) (Table 2). Pavements (mean hemeroby value of 8.5) also showed high percentages of adventives (20.5%) and neophytes (18.9%), the lowest percentages of which were found in phrygana and macchie vegetation which also had the lowest mean hemeroby values (3.4 and 3.0 respectively). Wasteland areas, mainly building plots, were examined separately in each ecological zone. In this habitat type, the highest percentages of adventives and neophytes were found in the outer central zone (Z_2), with 18.9% and 16.2%, respectively. In the wastelands of the inner city zone (Z_1), the adventives occurred with 18.6% and the neophytes with

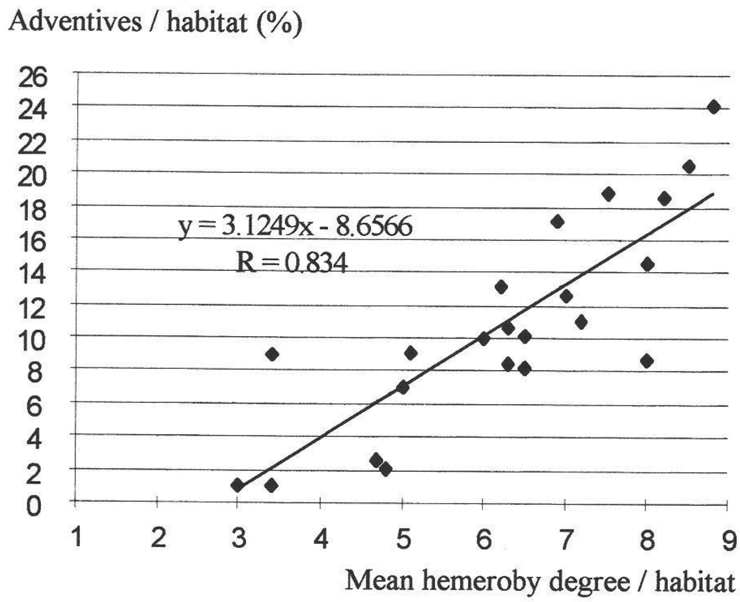

Fig. 2. Relation between the mean hemeroby degree per habitat and the percentage of adventives per habitat

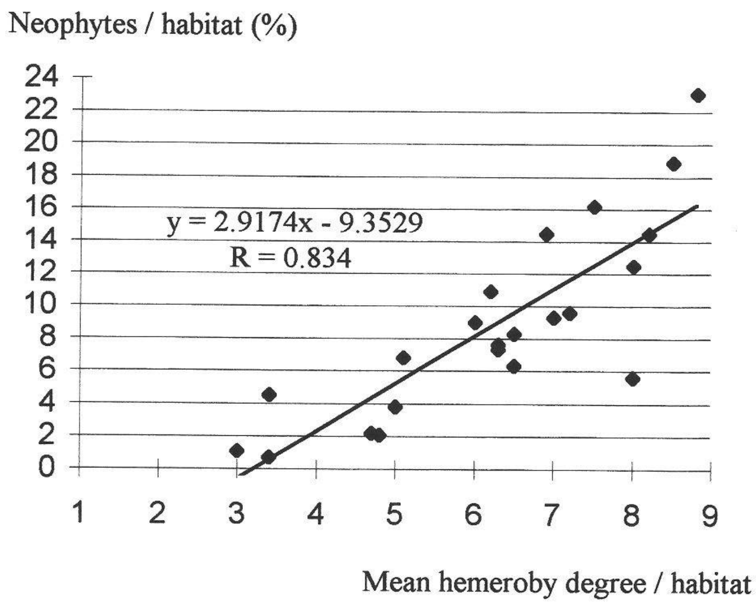

Fig. 3. Relation between the mean hemeroby degree per habitat and the percentage of neophytes per habitat

14.5%, whereas the suburban zone (Z_3) had 13.1% and 10.9%, and the outlying semi-rural zone (Z_4) had 8.2% and 6.3% adventives and neophytes respectively.

Tables 4 and 5 show that thirty-eight (40.9%) of the adventive taxa were fully established in Patras, ten (10.7%) were doubtfully established and forty-five (48.4%) were casuals. In the above three groups, most of the adventives were introduced to the area as ornamentals (39.5%, 60% and 51.1%, respectively) (Table 7). In addition, a significant number of established adventives (28.9%) were introduced by traffic and trade, and (42.3%) of casuals were introduced by agriculture.

Most of the established adventives (22 taxa, 57.9%) were stenohemerobic (with one to three degrees of hemeroby), and the majority of these (18 taxa, 81.8%) were confined to intensively influenced sites (seven to nine hemeroby degrees). Only two taxa (5.3%) could be characterized as euryhemerobic (over six hemeroby degrees, sensu Kowarik 1990). These were the archaeophytes *Arundo donax* and *Sinapis alba* subsp. *alba* (Table 5). Established adventives with hemeroby degrees of four to six (14 taxa, 36.8%) constituted an intermediate group which was not taken into account here (see also Kowarik 1990).

4. Discussion

4.1 Proportion of adventives

We consider Patras a typical Greek and Mediterranean city and its percentages of adventives (11.4%) and neophytes (8.9%) are comparable with those of other Mediterranean cities in central and southern Italy (see Celesti Grapow et al. 1996). However, Patras has a much lower percentage of adventives than cities of northern Italy and central Europe that have a continental climate. For example, in Turin (N. Italy) the adventive flora is about 20% (Siniscalco and Barni 1993–94), while in Milan and West Berlin, neophytes alone account for 21.4% and 29.7% of the total flora, respectively (Kowarik 1990, Celesti Grapow et al. 1996).

4.2 Origin, time and method of introduction

Taxa of American and Asiatic origin dominate the adventive flora of Patras and this is also the case in Mediterranean (Quezel et al. 1990, Celesti Grapow 1993–94) and central European (Pyšek et al. 1995, Sukopp 1995) regions.

Neophytes compose most of the adventive flora of Patras (73 taxa, 78.5%) and reached the area, intentionally or unintentionally, after the discovery of America and the subsequent increase in international trade. The port of Patras has played a strong role in the introduction of adventive taxa. From 1830 to the start of the second world war, the port received intense commercial activity, mainly from Italy, Sicily, Malta and, to a lesser degree America (Triantaphillou 1995), and it is likely that during this period the majority of neophytes were introduced to the area via these shipping routes. Examples of neophytes introduced this way are: *Aster squamatus*, *Conyza albida*, *C. bonariesis*, *Coronopus didymus*, *Oxalis pes-caprae*. Because of its geographical location ("Gate to the west"), the city of Patras is considered the prime importation and distribution centre of the adventive taxa within western Greece.

Archaeophytes recorded in the adventive (21.5%) and total flora (2.5%) of Patras, are fewer than those recorded in other cities of Central Europe (e.g. Kowarik 1990, Landolt 1991). These plants are difficult to distinguish because they have merged greatly into the native Greek flora. This can be explained by traditional agricultural methods (through which the archaeophytes were introduced) that started in Mesopotamia around 7000 BC and arrived in Greece earlier (ca. 6500–6000 BC) than the rest of Europe (5500–4000 BC) (see Lang 1994). Archaeophytes identified in this study are common species, cultivated in Greece since ancient times (e.g. *Allium cepa*, *Cicer arietinum*, *Hordeum vulgare*, *Ricinus communis*) (Table 5).

Ornamental plants escaped from cultivation are the major source of adventives in Patras as they compose almost half the city's adventive flora (47.3%) (Table 7). Typical examples of these ornamentals are: *Antirrhinum majus*, *Ipomoea indica*, *Mirabilis jalapa*, and *Tropae-*

olum majus. Together with taxa introduced by agriculture (22.6%) and as bird fodder (1.1%) (Table 7), ornamentals form the group of "deliberately" introduced adventives and compose three quarters of the adventive flora of Patras.

4.3 Spatial distribution of adventives

The spatial analysis of adventives in relation to the ecological zones of Patras (Table 8), show that the total number of adventives increases from the inner city zone (Z_1) to the outlying semi-rural zone (Z_4). The high numbers of adventives in the suburban (Z_3) and outlying semi-rural zones (z_4) are linked to agriculture (e.g. *Citrullus lanatus*, *Echinochloa colonum*, *Xanthium spinosum*) and gardens (e.g. *Asclepias curassavica*, *Cosmos bipinnatus*, *Persicaria capitata*), habitats both abundant in these zones. In contrast, as percentages of the total flora of each zone (Table 8), adventives and neophytes decrease from the inner city areas (Z_1, Z_2) to the less urbanized areas (Z_3, Z_4) (see also, Sukopp et al. 1979, Kunick 1982). The high percentage of adventives in the inner city and outer central zones, is due to human disturbance. This disturbance increases from the periphery to the centre of the city and is evident mainly from the "urban heat island", pollution and ruderal soils. Thus, many native taxa retreat or disappear because their natural habitats are destroyed and abiotic factors become unfavourable. In turn, secondary habitats such as ruins, building plots and paved surfaces form, and these favour the establishment of adventive taxa. Maximum percentages of adventives (21.1%) and neophytes (18%) were found in the outer central zone because the old part of the city belongs to this zone. In the old city, the presence of habitats such as old walls, archaeological sites and old gardens has led to the appearance of many adventive taxa such as *Cymbalaria muralis* subsp. *muralis*, *Nicotiana glauca*, *Ipomoea purpurea* and *Passiflora caerulea*. *Cymbalaria muralis* subsp. *muralis* and *Nicotiana glauca* are characteristic taxa of the old city of Patras and have also been reported common in other old city centres of southern Europe (Brandes 1995).

4.4 Response of adventive flora to human impact and different habitat types

The connection between adventive taxa, especially neophytes, and human impact has been reported in several studies (e.g. Sukopp and Werner 1983, Kowarik 1990, Sykora 1990). In Patras, we investigated this connection in ecological zones (Table 8) and single habitats (Table 2). Fig. 2 and 3 illustrate a strong trend for percentages of adventives, or neophytes, per habitat, to increase in proportion to the mean hemeroby value per habitat. The classification of the habitat types of Patras according to their mean hemeroby value (Table 2), led us to the following conclusions:

1. Habitats most strongly and constantly influenced by humans have high percentages of adventives and neophytes. According to Kowarik (1991) these habitats have hemeroby values of 7–9, while in Patras, values are ≥ 6.9. Most of these habitats are in the densely built-up and highly populated areas of the city. Tree beds have particularly high percentages of adventives (24.2%) and neophytes (23.1%), considering the small area (ca. 1 m^2) and the subsequent limited space available for plant growth. This may be attributed to the better adaptation of adventives to the specific ecological conditions of this kind of microhabitat. These specific ecological conditions include:

a) A warmer microclimate due to the high thermocapacity of the building materials surrounding a tree bed, such as cement and asphalt. The warmer microclimate favours the development mainly of thermophilous adventive taxa.

b) The deposition of litter, animal excrement, pollutants etc., on the tree beds, which creates conditions of hypertrophy and pollution. Combined with these conditions, the system-

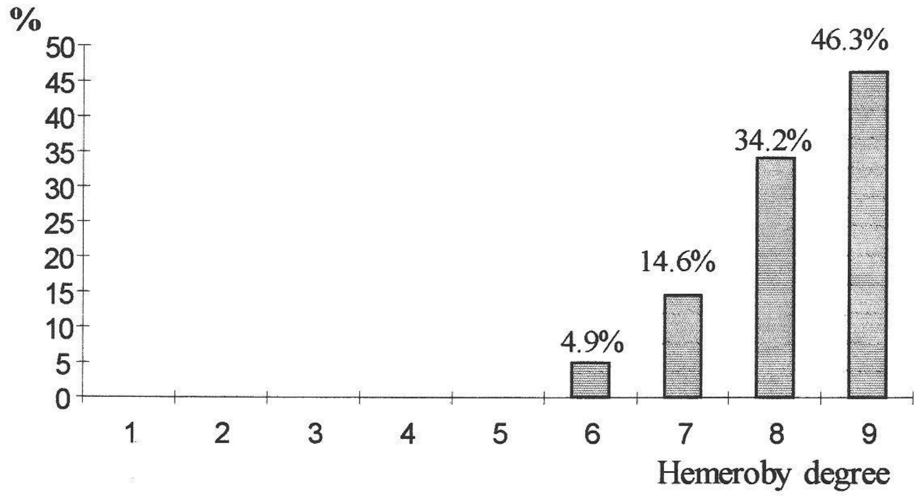

Fig. 4. Hemeroby spectrum of *Conyza bonariensis*. 100% = occurrence in 41 relevés, arithmetic mean: 8.2, standard deviation: 0.88, hemeroby indicator value = 8

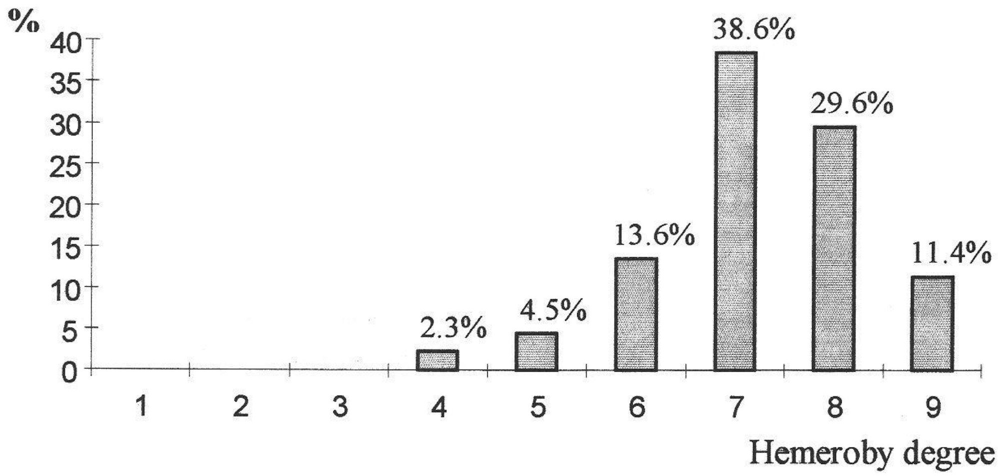

Fig. 5. Hemeroby spectrum of *Veronica persica*. 100% = occurrence in 44 relevés, arithmetic mean: 7.2, standard deviation: 1.12, hemeroby indicator value = 7

atic cleaning of tree beds decreases the competitive ability of native taxa and favours the establishment of adventives.

For similar reasons, pavements also have high percentages of adventives (20.5%) and neophytes (18.9%). Here, most of adventives (e.g. *Conyza bonariensis*, *Cyperus alternifolius*, *Euphorbia prostrata*) grow in crevices, where the space available for plant development is, presumably, even more limited.

Coastal wastelands, planted green areas and disused industrial areas have lower percentages of adventives (and neophytes), compared to other habitats with high human impact. For the first two habitats this is attributed mainly to the prevailing abiotic factors, such as the cooler microclimate (influence of sea, irrigation, etc.), that are more favourable to indigenous taxa. For the industrial areas, however, this is due to their abandonment in the last years and the lack of clearings. The growth of many native taxa in the above habitats reduces the invasiveness and competition of the mostly thermophilous and xerophilous adventives.

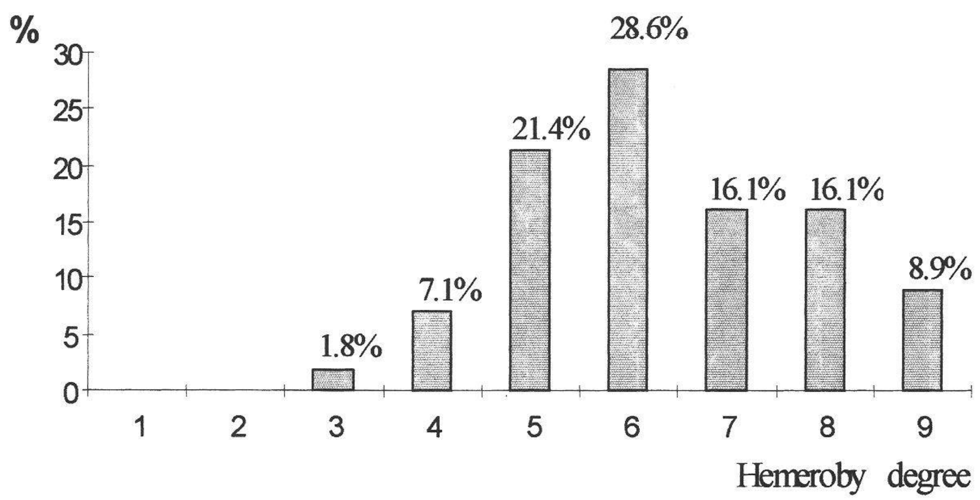

Fig. 6. Hemeroby spectrum of *Sinapis alba* subsp. *alba*. 100% = occurrence in 56 relevés, arithmetic mean: 6.3, standard deviation: 1.48, hemeroby indicator value = 6

Indicators of intensively disturbed habitats are the adventives *Conyza bonariensis* and *Veronica persica*, with hemeroby indicator values of 8 and 7, respectively (Fig. 4 and 5).

2. Habitats subject to medium and periodical human impact have low proportions of adventives and neophytes. According to Kowarik (1991) these habitats have hemeroby values of 4–6, while in Patras, values are 4.7–6.5. Fallow land, railway tracks, and wastelands in Z3 and Z4, have average percentages of adventives (8.2%–13.1%) but great floristic diversity (over 300 taxa). This diversity is explained by the combination of: a) the presence of many native taxa as relics from degraded, natural vegetation (mainly phrygana and macchie), and b) the wide range of human impact – from meso- to polyhemerobic (Tables 2 and 3). Therefore, a great variety of habitats with various degrees of naturalness form, and ensure the coexistence of non-synanthropic (native taxa of natural and semi-natural vegetation), and synanthropic taxa (adventives, apophytes, etc.).

One adventive indicating habitats of medium human disturbance is the archaeophyte *Sinapis alba* subsp. *alba* with a hemeroby indicator value of 6, and which is found mainly on fallow land (Fig. 6).

3. Seashores, urban forests, phrygana and macchie, have very low percentages of adventives which do not necessarily imply their definite establishment in these habitats. *Pinus halepensis* urban forest, macchie and phrygana approach the climax or subclimax vegetation of the study area, and prevent the establishment of new colonists mainly by competition. On seashores, where specialized plant communities (e.g. ammophilous) grow, establishment of adventives is also difficult despite localized, high human impact (H9). Thus, only the adventive *Carpobrotus edulis,* was found on some seashores around Patras. Together with wetlands and streams, the above habitats are the most natural elements within the study area. The establishment of adventives in wetland and stream habitats is difficult due to the presence of specialized plant communities. In Patras however, percentages of adventives were higher than expected. This is attributed to human activities such as debris and waste dumping, drainage, technical works (e.g. motorway construction near Agia swamp), and the resulting degradation of riparian and hygrophilous vegetation.

4. The proportion of wasteland adventives in each zone is of particular interest, as it corresponds roughly to the proportion of overall adventives in each zone (compare Tables 2

and 8). Consequently, wasteland areas are good indicators of the colonization degree of adventives in each zone. Therefore, the total percentage of adventives in each zone can be fairly accurately estimated by determining the number of wasteland adventives.

4.5 Establishment

A significant part of the adventive flora of Patras (40.9%, Table 4) has established fully. The five most characteristic and common established taxa of the city's adventive flora, which fulfil most the establishment criteria, are the neophytes *Aster squamatus*, *Conyza albida*, *C. bonariensis*, *Oxalis pes-caprae* and the archaeophyte *Sinapis alba* subsp. *alba* (Table 5).

Doubtfully established adventives compose a small part (10.7%) of the adventive flora of Patras (Table 4). This group contains taxa which can propagate spontaneously from generation to generation (e.g. *Bidens pilosa*, *Echinochloa colonum*, *Lippia canescens*); the other criteria are not sufficient to confirm their definite establishment (see Table 5). Therefore, the taxa of this group are gradually establishing in the flora of Patras.

Almost half the adventive taxa of Patras (48.4%) are casuals (Table 4). These, together with the doubtfully established taxa, may spread or disappear in the future, depending on whether they establish successfully in their new environment. Future status evaluation of these taxa may reveal their ability to spread and invade, and thus predict possible changes in the area's flora.

Ornamental taxa compose most the established adventives and therefore are the major source of established adventives in Patras (Table 7). *Mirabilis jalapa* is a typical ornamental that has established fully and spread progressively throughout several habitats of Patras during the last five years (see Table 5). Ornamentals also compose the majority of doubtfully established (60%) and casual (51.1%) adventives, and thus constitute an important reserve of possible, future fully established taxa (Table 7).

Inadvertently introduced taxa of traffic and trade and weeds of cultivation, have the greatest establishment success (eleven of fourteen, i.e. 78.6%, and six of eight taxa, i.e. 75%, respectively) (Table 7). In contrast, agricultural taxa, despite being cultivated in the area for several centuries, have very low establishment success. Of the twenty-one agricultural taxa recorded, only the archaeophytes *Arundo donax* and *Sinapis alba* subsp. *alba* have established. This small success rate is due mainly to the low competitiveness of the taxa, which allows them to exist only for a short time as casual escapes.

4.6 Naturalization status

Almost all of the established adventives in the study area: a) are more abundant and significantly competitive in disturbed sites only, b) are stable elements of synanthropic vegetation, and thus have an epoecophytic degree of naturalization (epoecophytes, i.e. taxa which hold a stable position inside the actual anthropogenous vegetation, but not in the natural vegetation, sensu Thellung 1915 and Schröder 1974). These conclusions are further supported as most of the established taxa (22 taxa, 57.9%) are stenohemerobic, and the majority of these (18 taxa, 81.8%) grow exclusively in α-euhemerobic to polyhemerobic habitats (see Tables 3 and 5).

In contrast to the above, only eight established adventives have succeeded in entering habitats with a lower degree of human impact (mesohemerobic or meso- to β-euhemerobic) (Table 5). These eight adventives are: *Agave americana*, *Arundo donax*, *Cymbalaria muralis* subsp. *muralis*, *Opuntia ficus-barbarica*, *Oxalis pes-caprae*, *Phalaris canariensis*, *Robinia pseudoacacia* and *Sinapis alba* subsp. *alba*. *Agave americana* and *Opuntia ficus-barbarica* thrive especially well in semi-natural habitats (degraded phrygana) and compete successfully, on a local scale, with the existing vegetation. We characterize these taxa as hemiagriophytes, i.e. naturalized in semi-natural communities (sensu Kornas 1990) in the area of Patras. The presence of the other six taxa in habitats with higher degrees of naturalness is either due to chance (e.g. *Phalaris canariensis* in macchie vegetation was possible introduced by bird excrement), or local invasions into "vacant" ecological niches created by human disturbances (e.g. *Oxalis pes-caprae*).

According to our observations, *Agave americana, Arundo donax, Opuntia ficus-barbarica, Oxalis pes-caprae* and *Robinia pseudoacacia* are the only adventive taxa found mostly in natural or semi-natural habitats of Greek landscape (e.g. *Arundo donax* near streams and wetlands, *Agave americana* and *Opuntia ficus-barbarica* in phrygana, *Oxalis pes-caprae* in a wide range of habitats, and *Robinia pseudoacacia* near rivers and forests). In some cases these taxa are very invasive and are considered agriophytes, i.e. alien taxa which hold a stable position in the present natural vegetation, but not in the original natural vegetation (sensu Schröder 1974). The number of agriophytic adventives in Greece is negligible compared to that of central Europe (see Lohmeyer and Sukopp 1992).

The low percentage of adventives in the flora of Patras, high numbers of epoecophytes, and the lack of agriophytes, especially compared to central Europe, is attributed to:

a) The great stability of the Greek flora due to its richness and diversity (ca. 5700 taxa of different phytogeographical origin), together with its history of human impact which makes Greek ecosystems resistant to invasions of new taxa, and

b) The significant enrichment of the synanthropic flora of Patras with apophytes. The most common apophytes such as *Brachypodium distachyon, Catapodium rigidum, Saxifraga tridactylites, Sedum cepaea*, originate from phrygana vegetation and generally from dry habitats of outer non-urban areas.

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