Advances in Biology & Earth Sciences
Vol.4, No.1, 2019, pp.12-25

DIFFERENT TYPES OF POLLINATION AGENTS AND INVASIVE PLANTS PHENOLOGY AS A VECTOR OF INVASIVENESS

Senka Barudanović[1,2], Emina Zečić[1,2*], Mašić Ermin[1,2]

[1]University of Sarajevo, Faculty of Science, Department of Biology, Sarajevo,
Bosnia and Herzegovina
[2]Centre for Ecology and Natural Resources - Academician Sulejman Redžić, Sarajevo,
Bosnia and Herzegovina

Abstract. The phenology patterns of invasive plants and other plants in weed communities were studied in the central part of Bosnia and Herzegovina, in the area of Zenica town which has been under the strong anthropogenic influence for decades. The phenology of invasive plant species was analyzed and compared with the phenology of other, non-invasive plants within the examined weed communities. The phytocoenological research was conducted on selected control points by means of standard Zurich-Montpellier school (Braun-Blanquet method, 1964). Biological attributes (Landolt *et al*., 2010) are assigned to phytocoenological relevé in which the processes of four types of biological behavior were analyzed: dispersal of diaspores (DA), vegetative dispersal (VA), flowering period (BZ) and pollination agents (BS). The phenology of invasive plant species was analyzed and compared with the phenology of other plants within the examined weed communities. The main aim of this research is to determine the basic differences between the phenology of invasive alien plants and weed species in the studied area. The results indicate that, when compared with other species of studied plant communities, the advantages of invasive plants are the following: dispersal by air currents over long distances, various ways of reproduction and higher intensity of flowering by the end of vegetation season.

Keywords: *invasive plants, phenology patterns, pollination agents, weeds.*

[*]***Corresponding Author:*** *Emina Zečić, Faculty of Science, University of Sarajevo, Zmaja od Bosne 33–35 Sarajevo, Bosnia and Herzegovina, Phone: +38760 31 51 149, e-mail: emina@zecic.org*

Received*: 05 November 2018;* ***Accepted****: 21 February 2019;* ***Published****: 10 April 2019.*

1. Introduction

Phenology is the field concerned with the periodicity of plant life cycles (leafing, flowering and fruiting) which are under the influence of periodical climate changes (Allaby, 2005).

Based on this, research that correlates with the phenology of plants and their invasiveness has been conducted. Invasive plant species are considered to be one of the most important direct drivers of biodiversity loss and ecosystem service changes (EEA, 2012).

Researches of invasive alien species in Europe and their negative impact on biodiversity are numerous (Borišić *et al*., 2018; Küzmič & Šilc, 2017; Maslo, 2016), however, there is a significant lack of information regarding their phenology.

Little attention has been given to the effect of the growing number of invasive plants on pollination of non–invasive plants, although competition for pollination can be an important factor in plant reproduction (Brown & Mitchell, 2001).

Although several studies have found certain connections between invasive plant phenology and their invasiveness, invasion ecology studies are mostly focused on the invasion process and aiming to predict invasions (Godoy *et al*., 2008; Pyšek & Richardson, 2010, 2006).

Specific reproductive attributes, as an advantage of invasive species, may be expected to be more relevant for long-distance colonization and vegetative dispersion can prevail in achieving local dominance. Research that related both types of traits to abundance, studied the Mediterranean islands, so it is suggested to do further research to test this hypothesis (Lloret *et al*., 2005).

This research was aimed at establishing the differences between the biological behavior of invasive plants and other, non–invasive plants within eight weeds communities. The following questions have been posed: Does the phenology of invasive plants within weed communities increase their invasiveness? What is the role of pollination agents, various ways of diaspore dispersal and the possibility of reproduction in various ways?

2. Material and methods

Comparisons research, focused on biological behavior between invasive plants and other plants within weed communities, was carried out by means of field and laboratory phases. Floristic and vegetation study was conducted through vegetation period from May 2017 to September 2017 by the standard Zurich-Montpellier school (Braun–Blanquet method, 1964).

Field research included 15 locations in the urban and rural area near the town of Zenica. After conducted fieldwork, results were synthesized in the laboratory.

Biological attributes are assigned to phytocoenological relevé in which process four types of biological behavior were analyzed: dispersal of diaspores (DA), vegetative dispersal (VA), flowering period (BZ) and pollination agents (BS). Types of biological behavior according to Landolt et al. (2010) are shown in Table 1.

Data processing was conducted using Microsoft Excel (2010). The names of the plant species are adjusted according to the Euro-Med PlantBase (http://ww2.bgbm.org/EuroPlusMed/query.asp).

3. Results

During the field phase on 15 localities, 76 phytocoenological relevés were carried out. In the laboratory phase, as well as in the field phase eight habitat types were identified as follows: *Matricarietum discoideae* Lakušić *et al*., 1975, stage *Artemisia verlotiorum, Helianthetum tuberosi* Oberd, 1967, *Sambucetum ebuli* Feföldy, 1942, stage *Parthenocissus quinquefolia–Reynoutria japonica, Artemisietum vulgaris* Tx. 1942, stage *Ailanthus altissima, Artemisietum vulgaris* Tx. 1942, stage *Ambrosia artemisiifolia, Chenopodion muralis* Br.–Bl. (1931) 1936, stage *Rubus caesius, Senecion fluviatilis* Tx. 1950 and *Artemisietum vulgaris* Tx. 1942.

Table 1. Assigned biological attributes (Landolt *et al*., 2010)
analyzed types of biological behaviour

Dispersal of diaspores (DA)	Vegetative dispersal (VA)	Pollination agents (BS)
At anthropochory	**Ao** above-ground runners	**am** pollinated by ants
Au autochory	**Au** below-ground runners	**an** anemogamous
Bo boleochory	**As** parts breaking off	**ap** apogamous
Dy dysochory	**Bz** bulbs	**au** autogamous
En endochory	**Ho** tussocks, tufts	**ca** cantharophilous
Ep epichory	**Kr** creeping rhizome	**en** entomogamous
Hy hydrochory	**Kt** creeping shoots or espaliers	**hd** hydrogamous
Kd unknown	**Kv** no vegetative dispersal parts	**hm** hymenopterophilous
Me meteorochory	**Po** cushions	**le** lepidopterophilous
My myrmecochory	**Sb** bulbils	**me** melittophilous
	Sr basal lateral shoots	**mo** mostly without flowers
	Sw above-ground shoots	**my** myophilous
	Ws root shoots	**of** mostly without ripe fruits
		or ornithophilous
		ph phalaenophilous
		ps psychophilous
		sn pollinated by snails
		sp sphingophilous
		ve vespidophilous
		wa pollinated by heteroptera
		() inferior importance
		? doubtful information
		?? species mentioned in at least one of the three works Knuth (1898, 1899), Oberdorfer (2001), Rothmaler et al. (2005)

Description of identified habitat types

Association: *Matricarietum discoideae* Lakušić *et al*. 1975

Plant communities with common mugwort have a wide ecological valence in relation to humidity. They are spread throughout moderately humid habitats of neglected areas in suburbs and rural areas, on raised banks of rivers and streams, damp landfills and construction waste areas (Barudanović *et al*., 2015). Characteristic species for this community are: *Matricaria chamomilla* L. and *Artemisia verlotiorum* Lamotte and common invasive species are *Amaranthus retroflexus* L. *and Artemisia annua* L.

Association: *Helianthetum tuberosi* Oberd. 1967

The association belongs to the ecosystems of dry landfills. Association *Helianthetum tuberosi* Oberd. 1967 have been differentiated depending on soil nitrification, which can vary from moderate to extreme. Dominant species in this plant community is *Helianthus tuberosus* L., which is an indicator of habitat that is moderately rich in nitrogen and moderate in humus content. Characteristic invasive species observed in this association are: *Ailanthus altissima* (Mill.) Swingle, *Ambrosia artemisiifolia* L., *Artemisia annua* L., *Erigeron canadensis* L., *Erigeron annuus* (L.) Desf., *Helianthus tuberosus* L., *Reynoutria japonica* Houtt., *Robinia pseudoacacia* L., *Rhus typhina* L., and *Xanthium strumarium* ssp. *italicum* (Morreti) Greuter.

Association: *Sambucetum ebuli* Feföldy 1942

Association *Sambucetum ebuli* presents a nitrophilic and sciophilous ruderal vegetation, which prefers shaded habitat along the edges of roads and railroad tracks, forest edges, fences, along the rivers, abandoned buildings and damp landfills. Indicator species which forms dense formations is *Sambucus ebulus* L. Species belonging to this community are adapted to semi-humid habitats and they are indifferent towards soil reaction. They prefer sunny, slightly shaded places with relatively deep soils. A larger number of invasive plants that are registered within this association *are: Acer negundo* L., *Ailanthus altissima* (Mill.) Swingle, *Amaranthus retroflexus* L., *Ambrosia artemisiifolia* L., *Erigeron canadensis* L., *Erigeron annuus* (L.) Desf., *Gleditsia triacanthos* L., *Helianthus tuberosus* L., *Impatiens glandulifera* Royale, *Parthenocissus quinquefolia* (L.) Planch. in Candolle & Candolle, *Phytolacca americana* L., *Reynoutria japonica* Houtt. and *Robinia pseudoacacia* L.

Association: Artemisietum vulgaris Tx. 1942, stage *Ailanthus altissima,*

This community belongs to the ecosystems of dry landfills. Species which constitute this association survive in sunny places and in moderately nitrified and moderately humid soil. These are very resistant plant species which quickly adapt and spread. Beside *Ailanthus altissima* (Mill.) Swingle, other invasive plant species are well developed such as *Artemisia verlotiorum* Lamotte, *Erigeron canadensis* L., *Helianthus tuberosus* L., *Parthenocissus quinquefolia* (L.) Planch. in Candolle & Candolle, *Phytolacca americana* L., *Reynoutria japonica* Houtt. and *Robinia pseudoacacia* L.

Association: *Artemisietum vulgaris* Tx. 1942, stage *Ambrosia artemisiifolia*

This association belongs to the ecosystem of dry landfills. This association is characteristic for the ruderal habitats in continental areas. Indicator species of this type of association is *Artemisia vulgaris*, but very often this species is accompanied with the invasive species *Ambrosia artemisiifolia* L. In addition to this invasive species, a more invasive species growth is evident in the community as follows: *Acer negundo* L., *Amaranthus retroflexus* L. *Bidens frondosa* L., *Erigeron annuus* (L.) Desf., *Helianthus tuberosus* L., *Erigeron canadensis* L., *Robinia pseudoacacia* L., *Solidago giganthea* Aiton and *Xanthium strumarium* ssp. *italicum* (Morreti) Greuter.

Alliance: Chenopodion muralis Br.–Bl. (1931) 1936, stage *Rubus caesius,*

Alliance *Chenopodium muralis* belongs to the ecosystem of arable lands. Plant species which inhabit arable lands are well adapted to frequent anthropogenic influences. Different methods which are very often changing in agriculture have a huge impact in process of colonization of arable lands. The most prominent plant species in this type of ecosystem are present with perennial plants that form strong rhizomes, and the presence of therophytes are smaller. Plants which inhabit this type of ecosystems grow in shady and relatively wet soils which are rich in nitrates. Prominent invasive species which are recorded in this community are: *Acer negundo L*., *Ailanthus altissima* (Mill.) Swingle, *Amaranthus retroflexus* L., *Ambrosia artemisiifolia* L., *Artemisia annua* L., *Erigeron canadensis* L., *Erigeron annuus* (L.) Desf., *Phytolacca americana* L., *Robinia pseudoacacia* L. *and Solidago giganthea* Aiton.

Alliance: Senecion fluviatilis Tx. 1950

Alliance *Senecio fluviatilis* belongs to the ecosystems of moist dump. This community is developed along river banks, streams, canals and places where wastewater is discharged. Optimum of vegetation development is during the months of July and August. Due to strong anthropogenic pressures, such as pollution of rivers, river banks and additional fertilization, the floristic composition of communities is somewhat altered, in favor of nitrophilous species in the coastal regions of these ecosystems (Barudanović *et al*., 2015). Prominent invasive alien species of this alliance are: *Acer negundo L*., *Artemisia verlotiorum* Lamotte, *Echinocystis lobata* (Michx.) Torr. & A. Gray, *Erigeron annuus* (L.) Desf., *Helianthus tuberosus* L., *Parthenocissus quinquefolia* (L.) Planch. in Candolle & Candolle *and Xanthium strumarium* ssp. *italicum* (Morreti) Greuter.

Association: Artemisietum vulgaris Tx. 1942.

This community, like the previous one, belongs to the ecosystem of moist dump. The community is characteristic of a dry and sunny habitat. Indicator species of this association is *Artemisia vulgaris* L., but a significant number of invasive alien species have been recorded in this community as follows: *Acer negundo* L., *Ailanthus altissima* (Mill.) Swingle, *Amaranthus retroflexus* L. *Ambrosia artemisiifolia* L., *Artemisia verlotiorum* Lamotte, *Erigeron canadensis* L., *Echinocystis lobata* (Michx.) Torr. & A. Gray, *Erigeron annuus* (L.) Desf., *Phytolacca americana* L., *Reynoutria japonica* Houtt., *Robinia pseudoacacia* L. *and Xanthium strumarium* ssp. *italicum* (Morreti) Greuter.

Invasive plant species within analyzed weed communities

In the area of Zenica town the tertiary ruderal vegetation suitable for growth and dispersal of a relatively large number of invasive plant species were analyzed and the qualitative assessment of plant communities was made. The analysis revealed that there were more than 22% invasive plant species present within the most examined weed communities. The biggest portion (Fig.1) of invasive plants was registered within the *Sambucetum ebuli* (38.46%) association and within the *Senecion fluviatilis* (36.36%) alliance. The lowest number of invasive species was recorded within the *Matricarietum discoideae* community (14.81%).

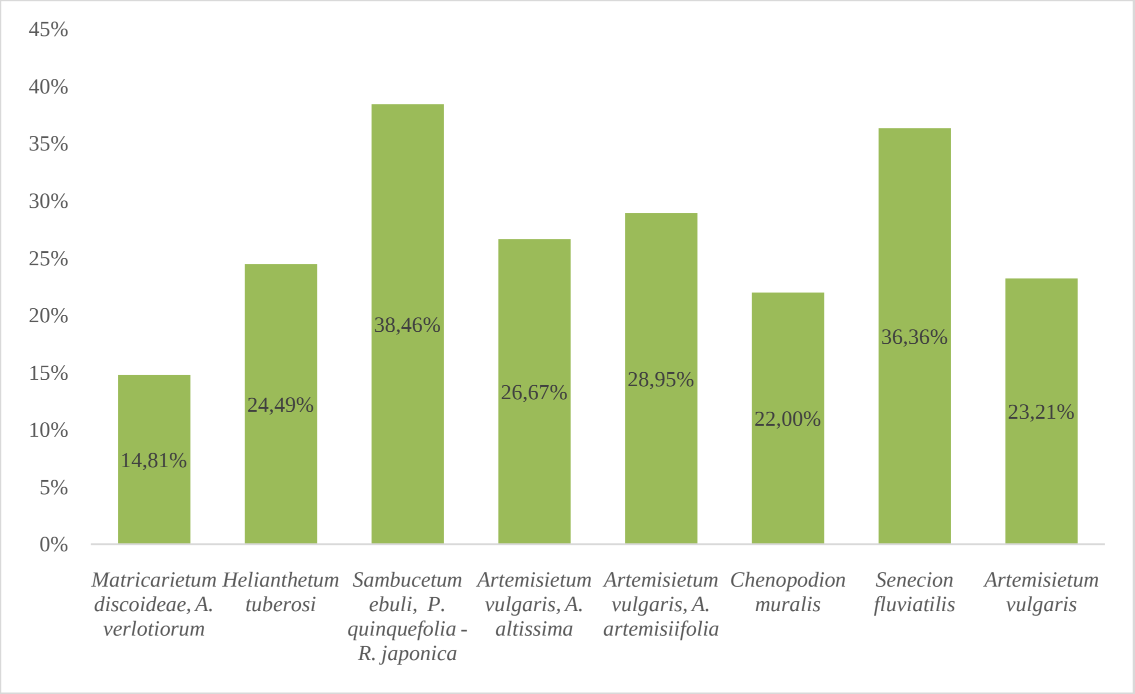

Fig.1. Invasive plant species within analyzed weed communities

Dispersal of diaspores (DA)

In the *Matricarietum discoideae* community (Fig.2) the most important species the ones whose are dispersed by animals, either by endochory (En), i.e. dispersal by passing through the animal's digestive system or by dysochory (Dy), i.e. when animals collect seeds and dispose of it sometime later to some other places. In the examined communities, the dispersal by air currents or meteorochory (Me) is also present. In invasive plant species, the dispersal by air currents is present the most, that is, dispersal of diaspores by wind. In this process diaspores have numerous characteristics enabling and facilitating their dispersal by wind over long distances. Diaspores of species within the community of *Senecion fluviatilis* and *Sambucetum ebuli* (stage *P. quinquefolia–R. japonica*) also disperse by air currents the most. The largest number of invasive plants was registered within the *Sambucetum ebuli* association (38.46%) and the *Senecion fluviatilis* alliance (36.36%). Seeds of invasive plants have different mechanisms, which enable them to disperse by air currents (Me) over long distances. There is certain connection between the manner of diaspore dispersal and distribution of species. The dispersal of diaspores by air currents is considered to be an important characteristic of invasive plants (Lloret *et al*., 2005).

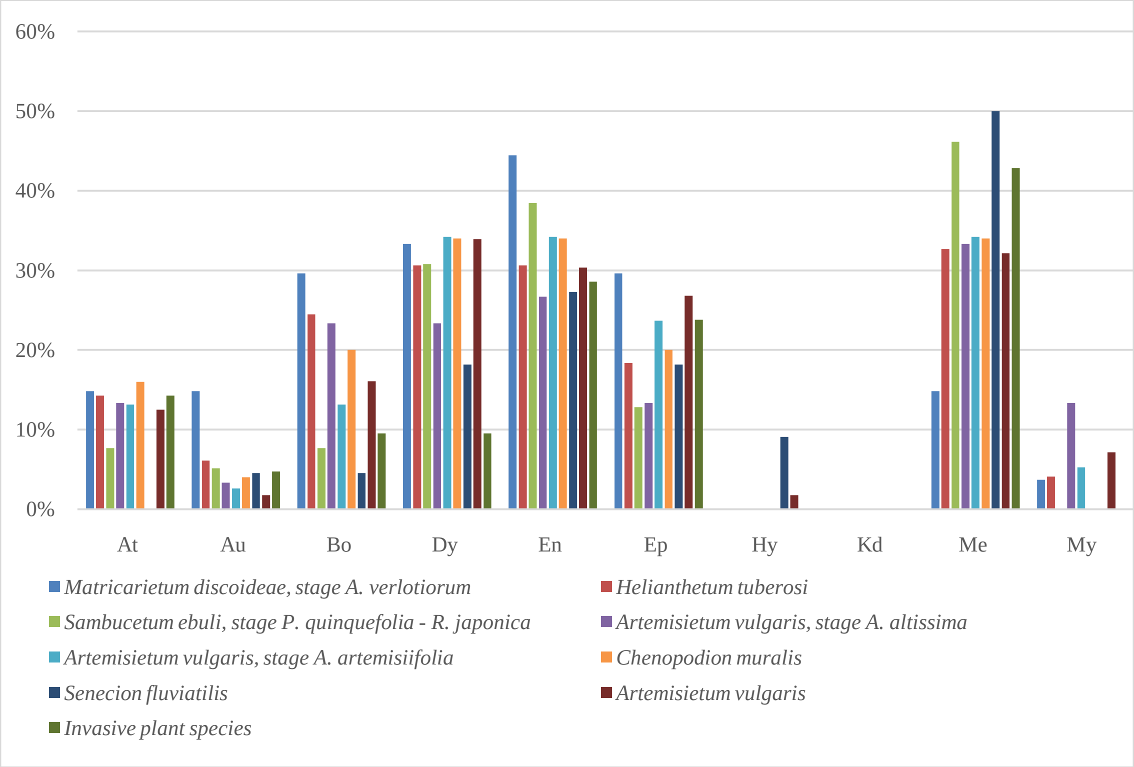

Fig. 2. Comparative review of diaspores dispersal types within analyzed plant communities (Diaspores dispersal types: **(At)** anthropochory, **(Au)** autochory, **(Bo)** boleochory, **(Dy)** dysochory, **(En)** endochory, **(Ep)** epichory, **(Hy)** hydrochory, **(Kd)** unknown, **(Me)** meteorochory, **(My)** myrmecochory)

Vegetative dispersal (VA)

In the studied communities (**Fig.**3) species that are dispersing by seeds or spores and that have no vegetative parts for distribution (Kv) are present the most as well as species that are dispersing by below-ground runners (Au) and basal lateral shoots (Sr). Species that have no vegetative parts for distribution are present the most among invasive plants and they are dispersing by seeds or spores. Around 38.09% of examined invasive plants are dispersing by vegetative parts. The dispersal by below-ground runners (Au), long below-ground or submerged creeping runners and rhizomes (stolons) is present the most, which is the case with *Helianthus tuberosus* L., *Reynoutria japonica* Houtt and *Solidago gigantea* Aiton. For dispersal purposes, the species of *Ailanthus altissima* (Mill.) Swingle, *Rhus thyphina* L. and *Robinia pseudoacacia* L. are using root shoots (Ws), that is, shoots from lateral roots which are often far away from the main shoot. The dispersal by basal lateral shoots (Sr) is also present among species that are using different ways of reproduction.

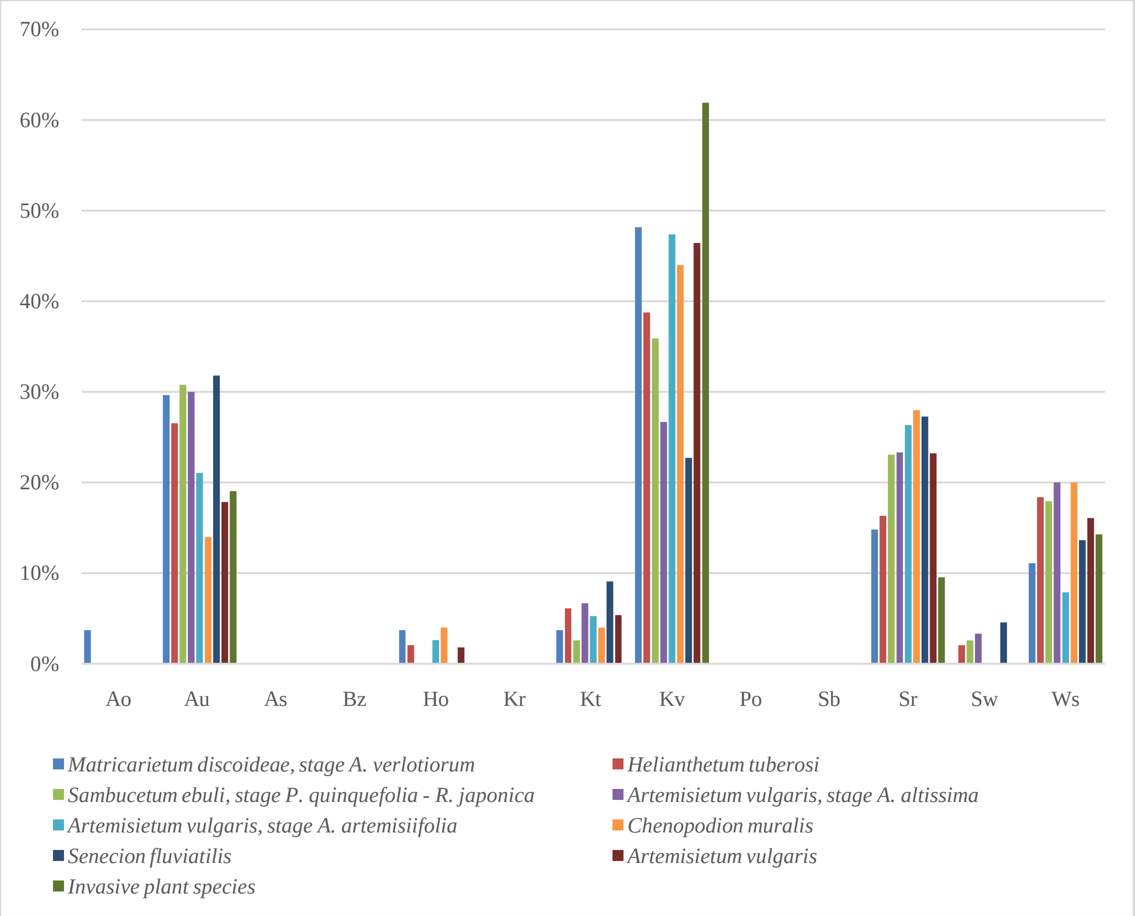

Fig. 3. Comparative review of vegetative dispersal types within analyzed plant communities (Vegetative dispersal types: **(Ao)** above-ground runners, **(Au)** below-ground runners, **(As)** parts breaking off, **(Bz)** bulbs, **(Ho)** tussocks, tufts, **(Kr)** creeping rhizome, **(Kt)** creeping shoots or espaliers, **(Kv)** no vegetative dispersal parts, **(Po)** cushions, **(Sb)** bulbils, **(Sr)** basal lateral shoots, **(Sw)** above-ground shoots, **(Ws)** root shoots)

Flowering period (BZ)

The most studied weed communities flower from March until November (Fig.4). The flowering period starts in March with a small number of flowering plants. Their number progressively increases during April, May and June and the highest intensity of flowering is during July, August and September. The flowering period gradually ends in October and November. The mentioned invasive plants from this area start flowering in April and May and the largest number of invasive plants flower during July, August and September. The considerable amount of invasive plants flower in October (42.86%) and at that time weed plants finish their flowering period. Although the plants within the examined weed communities have a similar flowering period, the flowering intensity of invasive plant species is still higher in October, when the flowering period for the most weed communities finishes. Longer flowering period enables the pollination agents to pollinate the flowering plants longer, which additionally affects the successfulness of their reproduction and the increased reproduction of plants increases the intensity of invasiveness too. Longer flowering period increases the probability of pollination and successful reproduction under conditions where pollination is seasonal or where the competition for pollinators is present (Lloret *et al*., 2005).

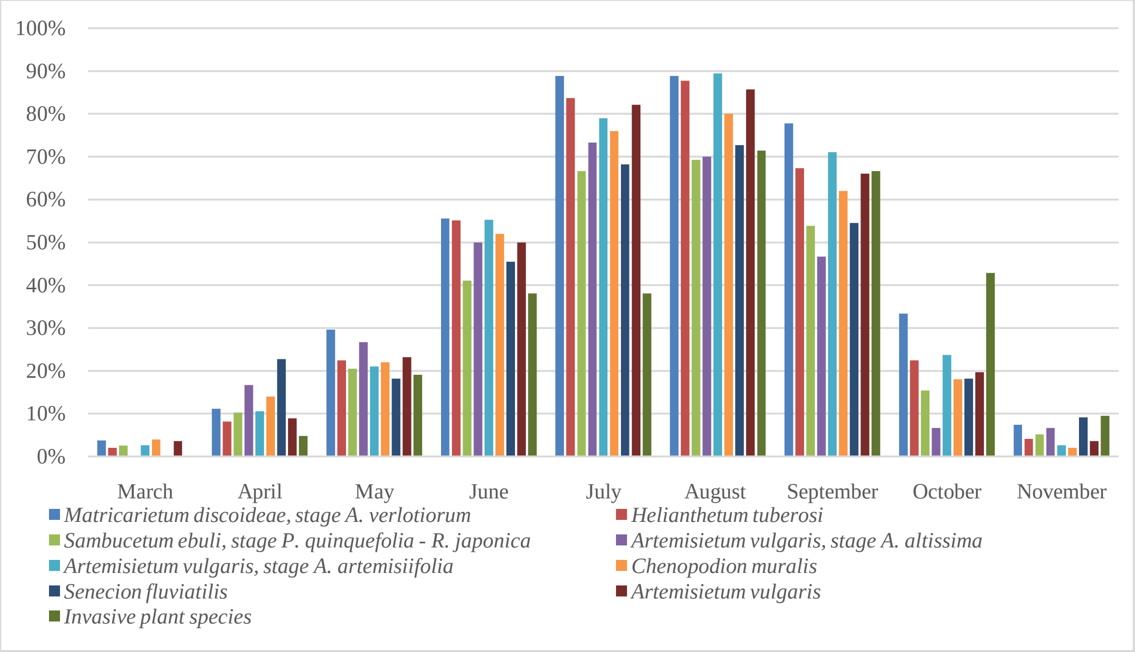

Fig. 4. Comparative review of flowering period within analyzed plant communities

Pollination agents (BS)

The most abundant species are those that are pollinated by bees and bumble-bees (me) and flies (my) (Fig.5). In most examined invasive plants, for which data about pollination agents have been available, the flowers are pollinated by wind (an) and insects (en). The same as in weed communities, among invasive plants there are also species which are pollinated by bees and bumble-bees (me) and flies (my). The pollination agents for around 28.57% of studied invasive plants are unknown, which provides incomplete picture about manners of pollination of those species. It is very important to mention that authors Landolt *et al*. (2010), describe that pollination agents of neophytes are extremely important for determining the potential of invasiveness of the plant species.

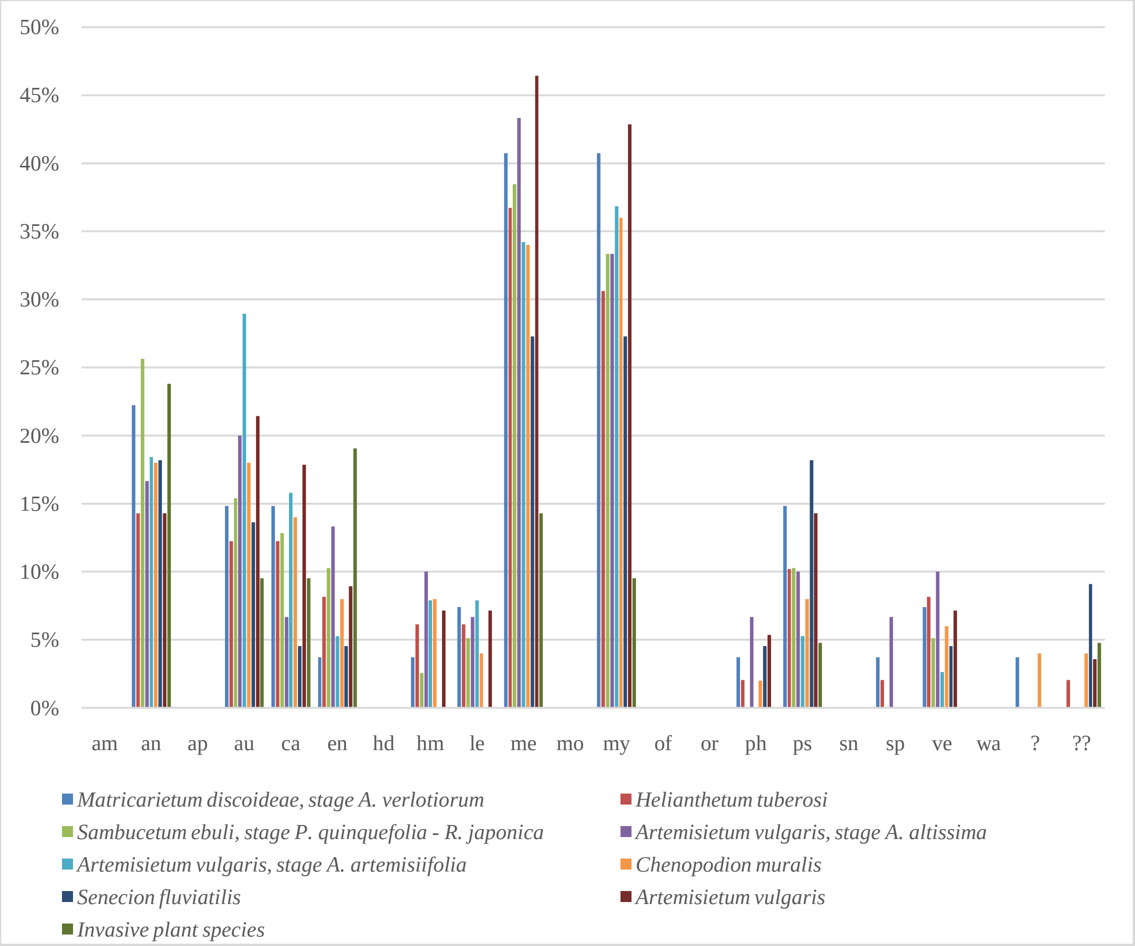

Fig. 5. Comparative review of pollination agents within analyzed plant communities (Pollination agents: **(am)** pollinated by ants, **(an)** anemogamous, **(ap)** apogamous, **(au)** autogamous, **(ca)** cantharophilous, **(en)** entomogamous, **(hd)** hydrogamous, **(hm)** hymenopterophilous, **(le)** lepidopterophilous, **(me)** melittophilous, **(mo)** mostly without flowers, **(my)** myophilous, **(of)** mostly without ripe fruits, **(or)** ornithophilous, **(ph)** phalaenophilous, **(ps)** psychophilous, **(sn)** pollinated by snails, **(sp)** sphingophilous, **(ve)** vespidophilous, **(wa)** pollinated by heteroptera, **()** inferior importance, **(?)** doubtful information, **(??)** species mentioned in at least one of the three works Knuth (1898, 1899), Oberdorfer (2001), Rothmaler *et al.* (2005)).

4. Discussion

Biological invasions threaten the world's biodiversity and the functioning of ecosystems. Over 13,000 plant species have successfully naturalized around the world, some of them have become invasive and there is no sign that their numbers will decrease in the near future. Therefore, policy and management decisions require predictive tools to better assess the likelihood of individual introduced species becoming invasive (Pyšek *et al*., 2017, Seebens *et al*., 2017, Andersen *et al*., 2004 in Divíšek *et al*., 2018., Gallager *et al*., 2014).

Whether the species that has been introduced into some new area is going to be invasive depends on its characteristics and characteristics of the ecosystem. The invasive species disperse without control, primarily because of the higher reproduction ability, fast growth and dispersal and resistance to various conditions of habitat (Pyšek & Richardson, 2010).

Ecosystems that are suitable for spreading of invasive plants are usually under strong direct, as well as indirect anthropogenic influences which led to degrading balance. Most of them are tertiary ecosystems or habitats that are similar to the original ecosystems of alien species, but without their natural predators (Dutta, 2018).

Human activities trigger changes in abiotic factors and give rise to several environmental issues. Additionally, a number of ecological problems also arise because of alterations in biotic interactions in ecosystems induced by humans (Dutta, 2017).

One such important issue is alien plant invasion, which is a formidable challenge to biodiversity conservation worldwide (Brooks *et al*., 2004), and unfortunately this issue has tremendous ecological, economic, and societal consequences (Davis *et al*., 2000).

The intensive dispersal of invasive plants by various ways of reproduction gives advantage to the invasive species over other species. During vegetation season these species create a huge number of diaspores that also have a capability to survive at resting stage (Catford *et al*., 2018).

Besides, their seeds have different mechanisms, which enable them to disperse by air currents over long distances. Invasive plants are capable of rapid spread of their population from the original source, over long distances. Production of small, light seeds allows them dispersal over considerable distances (Lake & Leishman, 2003).

Authors Gallagher *et al*. (2014) considered that multiple factors contribute to plant invasion success (e.g., functional traits, range characteristics, residence time, phylogeny), and they all must be taken into account simultaneously in order to identify meaningful correlations of invasion success.

Among investigated attributes, vegetative dispersal provides rapid expansion, increasing competitive ability and more efficient use of resources, but does not cause long-distance spread. In addition to the adaptability of invasive plants seeds to disperse over long distances, the most common invasive species of studied sites (approx. 38%) have the capability to simultaneously disperse by vegetative parts, which is the case with the following species: *Acer negundo* L., *Ailanthus altissima* (Mill.) Swingle, *Artemisia verlotiorum* Lamotte, *Helianthus tuberosus* L. *Reynoutria japonica* Houtt., *Rhus typhina* L., *Robinia pseudoacacia* L. and *Solidago gigantea* Aiton. Our data from this point of view correspond with literature data (Lloret, 2005, Jakobs *et al*., 2004, Suehs *et al*., 2004, Pysek *et al*., 1995).

Studied invasive plant species, for which there exists data about pollination agents, indicate that the flowers of these plants are mostly pollinated by wind and insects. Yet another study, that examined invasive woody plants, has shown results in which wind pollination is very important in potentially invasive species and insect pollination is more frequent in moderately and highly invasive alien species (Binggeli, 1996).

Author Byers (2017) reviewed phenomena of plant-pollinator interaction in a changing climate. According to this research, it is obvious that this interaction is potentially at risk due to climate change.

Ecological impacts of invasive plant species on pollinators, especially bees are reviewed by Stout and Morales (2009). According to their research, invasive plant species have positive, negative and non-existent effects on native pollinator communities. Invasive plant species affect native plants via physical mechanisms or competition for abiotic resources. In addition, competition for biotic resources, such as pollination services, can cause changes to community composition in invaded habitats. Impacts can be positive (invasive plants facilitate pollination of native species by acting as “magnets” and drawing pollinators into a plant community), negative (alien plants compete with native plants and reduce visitation and hence their pollination success) or non-existent (alien plants have no impacts on native ones). Our study has shown that the most abundant species are those that are pollinated by bees, bumble-bees and flies. In most studied invasive plants, for which data about pollination agents have been available, the flowers are pollinated by wind and insects. The same as in weed communities, among invasive plants, there are also species which are pollinated by bees, bumble-bees and flies. The pollination agents for around 28.57% of the studied invasive plants are unknown, which provides an incomplete picture about manners of pollination of those species. It is very important to mention that authors Landolt *et al*. (2010), describe that pollination agents of invasive plant species are extremely important for determining the potential of invasiveness of the plant species.

The plants within the examined weed communities also have similar mechanisms of dispersing as well as similar flowering period. The flowering intensity of invasive plant species, in addition to various mechanisms of vegetative reproduction and diaspores dispersal, is still higher in October when the flowering period for most weed plants ends. Longer flowering period enables the pollination agents to pollinate flowering plants longer, which additionally affects the successfulness of their reproduction. In another case species that have longer flowering period may have a greater total reproductive output and colonization potential (Baker, 1974, Lake & Leishman, 2003). It means that longer period of producing seeds allows them to take advantages of more colonization opportunities (Lake & Leishman, 2003).

Longer flowering period increases the probability of pollination and successful reproduction under conditions where pollination is seasonal or where the competition for pollinators is present. There is certain connection between the manner of diaspores dispersal and distribution of species, however, dispersal of diaspores by air currents is an important characteristic of invasive species (Lloret *et al*., 2005).

A group of authors carried out research about phenology of flowering of invasive alien species in comparison with native plants in three geographically remote regions with the Mediterranean type of climate in California, Spain and South Africa (Cape region). The flowering phenology is considered to be a potentially important component that affects the successfulness of growth and dispersing of introduced alien species given that the elevated fecundity of plants increases the intensity of invasiveness too. The research proved that the invasive alien species have different patterns of flowering phenology in comparison with native species in the three examined regions. Whether alien species are going to flower before, after or at the same time as native plants depends on the climate regime in the original ecosystems of invasive species and range of species that are considered to be invasive flora originating from other regions. The results of the research proved that the early flowering of plants is not the only reproductive strategy of dispersed invasive plants. The intensity of invasiveness can also be present in cases when they flower at the same time as native plants or after. Different flowering phenology is the consequence of different nature and human factors that may trigger and affect the reproductive relation between groups (Godoy *et al*., 2008).

5. Conclusion

The results of obtained range of indication values for dispersal of diaspores according to Landolt *et al*. (2010) suggest that the seed of studied invasive plant species is dispersed by air currents (Me) the most. The range of vegetative dispersal types shows that dispersal by seeds or spores (Kv) is present the most among invasive plants of studied plant communities. The highest flowering intensity of invasive plants is in August and September and contrary to weed plants, they have higher flowering intensity in October. The ranges of pollination agents indicate that the invasive plants of studied plant communities mostly comprise species that are pollinated by wind or insects. Apart from the fact that diaspores of studied species are dispersed by air currents on most occasions, the common invasive species of the studied locations (around 38%) have a capability to simultaneously disperse by vegetative parts, which is the case with the following species: *Acer negundo* L., *Ailanthus altissima* (Mill.) Swingle, *Helianthus tuberosus* L., *Reynoutria japonica* Houtt., *Rhus typhina* L., *Robinia pseudoacacia* L. and *Solidago gigantea* Aiton. When compared with other species of studied weed communities, the advantages of invasive plants are dispersal of diaspores by air currents over long distances, various manners of reproduction and higher intensity of flowering by the end of vegetation season. However, it is very important to highlight that phenology of invasive plants has not been sufficiently investigated and it is necessary to do further research with a larger number of different plant communities in order to establish a connection between pollination agents, invasive plants phenology and their invasiveness.

Acknowledgements

We thank the anonymous reviewer for valuable comments that substantially improved the manuscript.

References

Allaby, M. (2005). *Dictionary of Ecology*, Oxford University Press.

Andersen, M.C., Adams, H., Hope, B., Powell, M. (2004). Risk assessment for invasive species. *Risk. Anal.,* 24, 787–793.

Baker, H. (1974). The evolution of weeds. *Annual Review of Ecology and Systematics* 5, 1–24.

Barudanović, S., Macanović, A., Topalović-Trivunović, Lj., Cero, M. (2015). Ekosistemi Bosne i Hercegovine u funkciji održivog razvoja. Prirodno-matematički fakultet, Univerzitet u Sarajevu. pp. 1-55.

Binggeli, P. (1996). A taxonomic, biogeographical and ecological overview of invasive woody plants, *Journal of Vegetation Science, 7*, 121–124.

Boršić, I., Ješovnik, A., Mihinjač, T., Kutleša, P., Slivar, S., Cigrovski Mustafić, M. & Desnica, S. (2018). Invasive Alien Species of Union Concern (Regulation 1143/2014) in Croatia. *Nat. Croat., 27*(2), 357-398.

Brooks, M.L., D'Antonio, C.M., Richardson, D.M. (2004). Effects of invasive alien plants on fire regimes. *BioScience*, 54(7), 677-688.

Brown, J.B., Mitchell, J.R. (2001). Competition for pollination: effects of pollen of an invasive plant on seed set of a native congener, *Oecologia, 129*, 43–49.

Byers, D.L. (2017). Studying plant–pollinator interactions in a changing climate: A review of approaches. *Appl. Plant Sci.,* 5(6), 1700012.

Catford, J.A., Bode, M., Tilman, D. (2018). Introduced species that overcome life history tradeoffs can cause native extinctions. *Nature Communications*, 9, 2131.

Davis, M.A., Grime, P.J., Thompson, K. (2000). Fluctuating resources in plant communities: a general theory of invisibility. *Journal of Ecology*, 88, 528-534.

Divíšek, J.,Chytrý, M., Beckage, B., Gotelli, N.J., Lososová, Z., Pyšek, P., Richardson, D.M., Molofsky, J. (2018). Similarity of introduced plant species to native ones facilitates naturalization, but differences enhance invasion success. *Nature Communications,* 9, 1-10.

Dutta, H. (2018). Insights into the phenomenon of alien plant invasion and its synergistic interlinkage with three current ecological issues. *Journal of Asia-Pacific Biodiversity, 11*(2), 188-198.

Euro+Med (2006-): Euro+Med PlantBase - the information resource for Euro-Mediterranean plant diversity. Published on the Internet http://ww2.bgbm.org/EuroPlusMed/ [accessed *19.01.2019*].

European Environment Agency (2012). *The impacts of invasive alien species in Europe*. EEA Technical Report 16/2012.

Gallagher, R.V., Randall, R.P., Leishman, M.R. (2014). Trait differences between naturalized and invasive plant species independent of residence time and phylogeny. *Conservation Biology*, *29*(2), 360-369.

Godoy, O., Richardson, M. D., Valladares, F., Castro – Díez, P. (2009). Flowering phenology of invasive plant species compared with native species in three Mediterranean–type ecosystems, *Annals of Botany*, *103*(1), 485–494.

Jakobs, G., Weber, E., Edwards, P.J. (2004). Introduced plants of the invasive *Solidago gigantea* (Asteraceae) are larger and grow denser than conspecifies in the native range. *Diversity and Distribution*, 10, 11–19.

Küzmić, F., Šilc, U. (2017). Alien species in different habitat types of Slovenia: analysis of vegetation database. *Periodicorum Biologorum 119*(3), 199-208.

Lake, C.J., Leishman, R.M. (2003). Invasion success of exotic plants in natural ecosystems: the role of disturbance, plant attributes and freedom from herbivores, *Biological Conservation*, *117*, 215–226.

Landolt, E. (2010). *Flora indicativa*, Editions des Conservatoire et Jardin botaniques ville de Gèneve & Verlag Paul Haupt. Bern–Stuttgart–Wien.

Lloret, F., Médail, F., Brundu, G., Camarda, I., Moragues, E., Rita J., Lambdon, P., Hulme, E. P. (2005). Species attributes and invasion success by alien plants on Mediterranean islands, *Journal of Ecology*, *93*(3), 512–520.

Maslo, S. (2016). Preliminary list of Invasive alien species (IAS) in Bosnia and Herzegovina. *Herbologia*, *16*(1), 1-14.

Pyšek, P. et al. (2017). Naturalized alien flora of the world: species diversity, taxonomic and phylogenetic patterns, geographic distribution and global hotspots of plant invasion. *Preslia*, 89, 203–274.

Pyšek, P., Prach, K., Smilauer, P. (1995). Relating invasion success to plant traits: an analysis of the czech alien flora. Plant Invasions–*General Aspects and Social Problems* (eds P. Pysek, K. Prach, M. Rejmánek and M. Wadw), pp. 39–60. SPB Academic, Amsterdam.

Pyšek, P., Richardson, D.M. (2006). The biogeography of naturalization in alien plants. *Journal of Biogeography*. 33, 2040-2050.

Pyšek, P., Richardson, D.M. (2010). Invasive Species, Environmental Change and Management, and Health. *Annu. Rev. Environ. Resour.*, 35, 25-55.

Seebens, H. et al. (2017). No saturation in the accumulation of alien species worldwide. *Nat. Commun.*, 8, 14435.

Stout, C.J., Morales, C.L. (2009). Ecological impacts of invasive alies species on bees. *Apidologie*, *40*(3), 388-409.

Suehs, C.M., Affre, L., Médail, F. (2004). Invasion dynamics of two alien Carpobrotus (Aizoaceae) taxa on a Mediterranean island. I. Taxonomy, clonality and introgression. *Heredity*, 92, 31–40.