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Impacts of insect herbivory on reproductive success of *Ferulago glareosa* (Apiaceae)

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Abstract

Ferulago glareosa, which is considered to be a threatened species lives in two different habitat patches (Type 1 and Type 2) in Kemah, Erzincan (Turkey). In this study, in order to provide guidance to the possible conservation studies for species, we have examined both floral visitors and impact of visitors on fruit set. The visitor abundances of species and the impact of visitors on fruit set were determined by observing them for a period of 2 hours for 8 days spread in both 2016 and 2017. The fruit set of individuals in two habitat patches were measured by counting fruits of 587 rays in 60 individuals. The difference between fruit set of individuals in Type 1 and Type 2 patches was determined to be quite statistically significant (0.11 and 1.12 respectively). Omophlus caucasicus was observed to cause the biggest damage to the fruit set of species. Different abiotic conditions in the habitat patches and the flowering phenology of species were found to have an impact on the visibility of species to insect herbivores. As a conclusion, the damages given to species by insect herbivores were found to have a strong correlation with the spatial and temporal variations in species habitat.

Key words: Ferulago glareosa, insect herbivory, plant conservation, reproductive ecology, spatial variation

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Böcek otçulluğunun *Ferulago glareosa* (Apiaceae)'nın üreme başarısına etkileri

Özet

Tehdit altında tür olduğu öngörülen Ferulago glareosa Kemah, Erzincan (Türkiye)'de iki farklı habitat yamasında (Tip 1 ve Tip 2) yaşamaktadır. Bu çalışmada türe yönelik olası koruma çalışmalarına yön verebilmek için türün hem çiçek ziyaretçileri hem de ziyaretçilerin meyve tutumlarına etkileri araştırıldı. Ziyaretçi bollukları ve ziyaretçilerin meyve tutumlarına etkileri 2016 ve 2017 yıllarına yayılmış 8'er günde 2'şer saatlik zaman dilimlerinde gerçekleştirildi. İki habitat yamasındaki bireylerin meyve tutumları 60 bireyin 587 ışınındaki meyveler sayılarak saptandı. Tip 1 ve Tip 2 habitat yamalardaki meyve tutumlarının (0.11 ve 1.12 sırasıyla) istatiksel olarak oldukça farklı oldukları belirlendi. Türün meyve tutumuna Omophlus caucasicus'un en büyük zararı verdiği gözlemlendi. Habitat yamalarındaki değişik abiyotik koşulların ve türün çiçeklenme fenolojisinin türün böcek otçullarına görünürlüğünde etkin olduğu görüldü. Sonuç olarak, böcek otçulların türe verdiği zarar ile türün habitatlarındaki konumsal ve zamansal varyasyonlar arasında güçlü bir bağıntı olduğu saptandı.

Anahtar kelimeler: bitki koruma, böcek otçulluğu, Ferulago glareosa, konumsal varyasyon, üreme ekolojisi

1. Introduction

Conservation biology is the scientific study of the maintenance, loss and restoration of biological diversity. Although habitat degradation, overexploitation and climate change are the nearest causes of species extinction, reproductive failure is the ultimate cause. Reproductive ecology involves all aspects of reproductive matters and their interactions with biotic and abiotic components of the environment [1]. Reproductive failure results when there are

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constraints in one or several reproductive events [2] and, these constraints lead to a gradual reduction in population size and eventual extinction of the population. In the absence of data on reproductive ecology any conservation efforts remain ineffective [3].

The knowledge on the plant-pollinator interactions is another essential issue about the flowering plants' reproductive ecology. Several animal species visit flowers of most species. They don't all need to be pollinators. Therefore, in pollination ecology pollinators need to be distinguished from non-pollinating floral visitors. Most of the visitors that are not pollinator visit plants for nutrition purposes [1]. The impacts of the insect herbivory on the rare and endemic plants on the population-level were not understood well frequently suggested but seldom measured [4].

Ferulago glareosa Kandemir & Hedge (Apiaceae), which was first collected from Sürek village Kemah, Erzincan, (Turkey) in 2005 was introduced to the science world [5] (Figure 1). The individuals of species live on the slopes of hills with the vegetation cover less than 20%. The individuals with 370 and 186 flowers were observed in Sürek and Beşikli populations respectively. The species, whose population density is quite low, was determined to grow only in the young soil or in rock cracks on the bedrock. The IUCN Red List category for the species was proposed to be CR [B2ab(i, ii)] (Critical) [6].

Figure 1. The illustration of *F. glareosa*'s habitat.

F. glareosa grows in two different types of habitat patches (slopes) which look different in terms of many abiotic features. The patches regarded as "Type 1 patches'' here are highly steep slopes and the land is bare in terms of vegetation cover. The other patches regarded as "Type 2 patches" here have a thicker layer of young soil and a denser vegetation cover than Type 1 patches (Figure 2). No research on the reproductive ecology of species has been found to provide guidance to the possible conservation efforts. Therefore, the impact of the insect herbivory on reproductive success (as fruit set here) and insect visitors of *F. glareosa* constitute the main subjects of this research.

Figure 2. Overall picture of slopes (patches) where individuals of *F. glareosa* occupy
(Upper is Type 1 patches and below is Type 2 patches) (July 2017)

2. Materials and methods

2.1. *Determination of the visitor abundances and their impacts on fruit set*

The insect visitors were observed on buds, flowers and fruits of 25 individuals in Sürek population. The visitor abundances were observed for a period of 2 hours for 8 days spread to May, June and July in 2016 and 2017. We noted the damages given to buds, flowers and fruits (if any) by visitors after their interaction with the individuals of species. The visitors were imaged using Nikon D5100 camera in the field and using Nikon SMZ25 stereomicroscope in the laboratory. The identifications of the collected insect samples were carried out by consulting to expert [1].

2.2. *Determination of fruit sets*

Since we figured out that there might be significant differences in fruit sets of individuals in these different patches (Type 1 and Type 2 patches) in 2017, the fruit sets of individuals in these patches were determined separately. In order to determine the fruit sets of total 404 rays in 40 individuals, we tagged the umbels of 20 individuals from each patch in June and counted the number of fruits in July. We realized that the fruit set of individuals, which are short compared to the neighboring species in Type 2 patches were slightly damaged. Since we considered the visibility of their inflorescences to insect herbivores was reduced compared to the other individuals, we determined the fruit sets of 187 rays in 20 short mature individuals separately (Figure 3) [1].

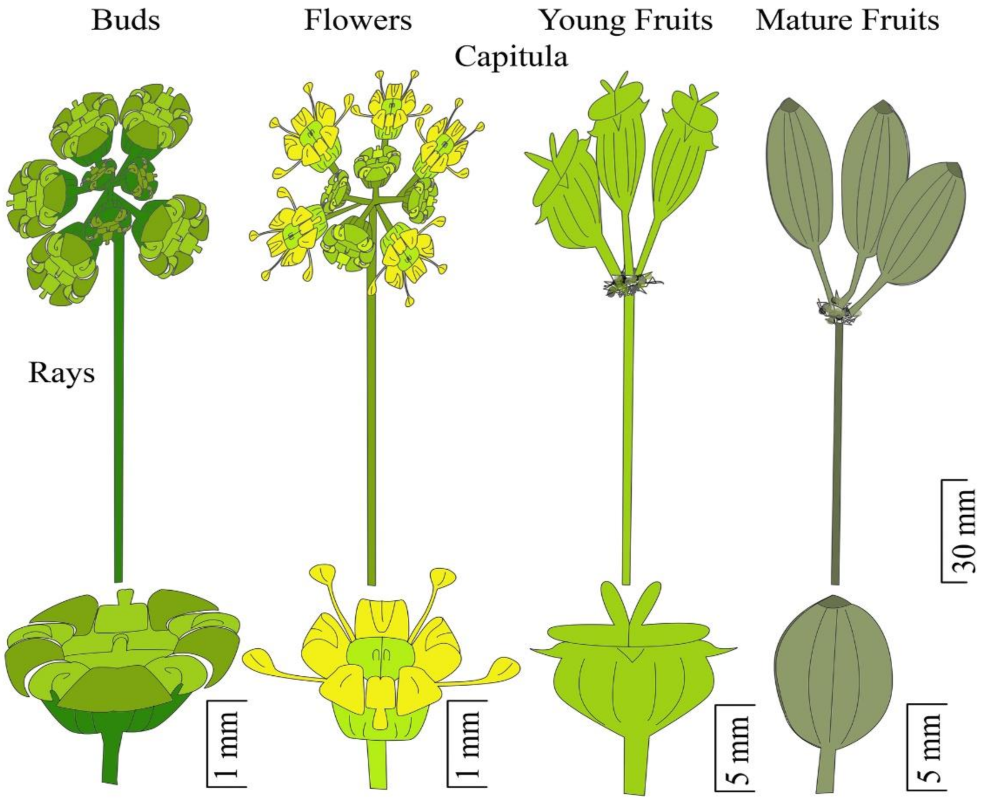

Figure 3. The illustration image of buds, flowers, young and mature fruits of *F. glareosa*.

2.3. *Preparation of the illustration images*

The illustration images were prepared by using pen, brush tools and 3D Map Generator-Terrain plugin of Photoshop CC 2018 software.

2.4. *Statistical analysis*

In order to determine if there was a statistically significant difference in the fruit sets between the individuals in two different habitat patches the independent samples t-test was performed. The statistical test was performed and the fruit set chart was generated using IBM SPSS Statistics 25 software.

3. Results

3.1. *Visitors of species*

Visitors of *F. glareosa* which were more abundant in number than other visitors and the plant structures they were active include:

On the buds of species; *Omophlus caucasicus* Kirsh, on the flowers of species; *Camponotus armeniacus* Arnoldi, *O. caucasicus, Mordellistena sp.*, *Clanoptilus heliophilus* Peyron, on the young fruits of species; *O. caucasicus*, *Tholagmus strigatus* Herrich-Schaeffer, *Graphosoma semipunctatum* Fabricius, on the mature fruits of species; *T. strigatus* and *G. semipunctatum.* In Figure 4, the most abundant visitors of *F. glareosa* and with which structures of species they interacted were illustrated.

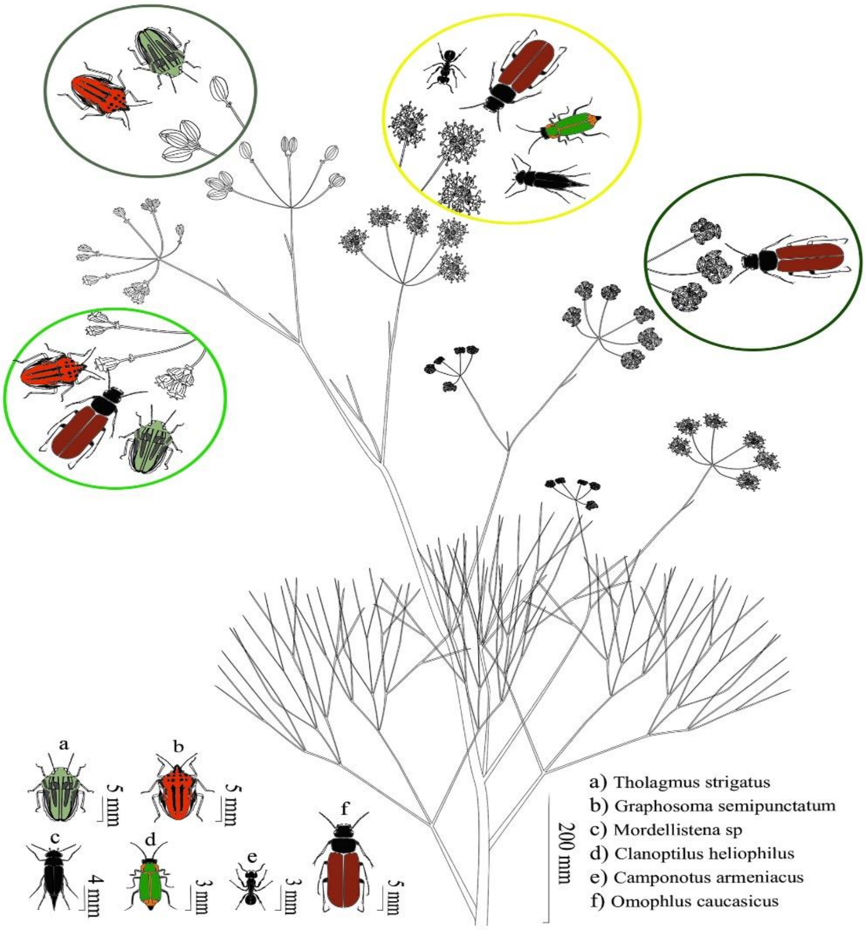

Figure 4. The illustration image of insects which were active on different flower/fruit stages

O. caucasicus which showed the greatest increase in its number between 2016 and 2017 years counted 105 and 245 respectively. The abundance of other species had declined considerably since flower/fruit structures to be visited decreased exceedingly because of insect herbivores (Figure 5). Aforementioned species' abundance decreased dramatically for *C. armeniacus* from 340 to 258; for *Mordellistena sp.* from 124 to 20; for *C. heliophilus* from 226 to 35; for *T. strigatus* from170 to 42*;* for *G. semipunctatum* from 110 to 54 in 2016 and 2017 respectively. So, any impact of other species on fruit set in individuals of *F. glareosa* could not be determined with sufficient data in 2017, but other careful observations made in 2016 showed that there was less harm to fruit set of species.

Figure 5. *O. caucasicus* and *F. glareosa* (Sürek population, June 2017)

3.2. *Fruit sets*

Figure 6 shows mean fruit sets per ray determined in individuals of Type 1 and Type 2 patches and in short individuals of Type 2 patches in Sürek population.

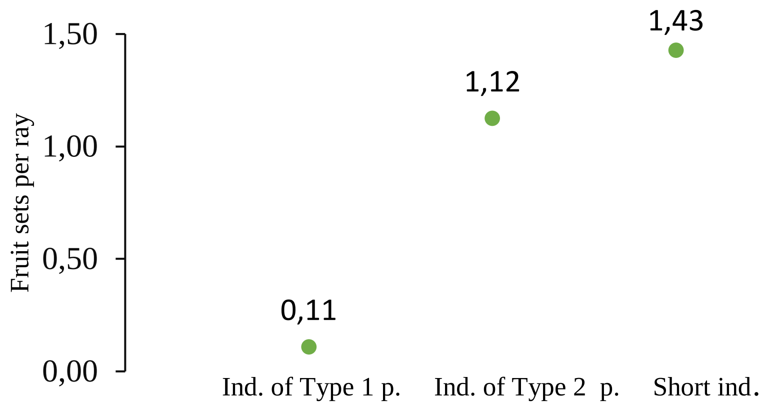

Figure 6. Mean fruit sets in individuals of Type 1 and Type 2 patches and in short individuals of Type 2 patches

3.3 *Statistical results*

Since the Sig (2-tailed) value was less than 0.05, this study found a very high statistical significance between the fruit set values per ray of individuals in Type 1 (0.1080 ± 0.17) and Type 2 patches (1.1240 ± 0.99) at 0.05 significance level ($t_{20.167} = -4.506$, $p < 0.001$) (Table 1 and 2).

Table 1. Group Statistics of fruit sets in different patches.
Group Statistics

	Patches	N Mean	Std. Deviation	Std. Error Mean
Fruit Sets	Type 1	20.1080	.17413	.03894
	Type 2	201.1240	.99317	.22208

Table 2. Independent Samples t Test of fruit sets in different patches
Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Fruit sets	Equal variances assumed	30.035	.000	-4.506	38	.000	-1.01600	.22547	-1.47243	-.55957
	Equal variances not assumed			-4.506	20.167	.000	-1.01600	.22547	-1.48607	-.54593

4. Conclusions and discussion

It might seem optimal to have large flowers that can be easily seen by pollinators; unfortunately, they can also be seen by herbivores and because ovules and pollens are rich in protein, they are good food sources for pests [7]. Although *F. glareosa* has small flowers, species' flowering phenology was observed to start at the end of May while many of the neighboring species in its habitat did not bloom in that period. Therefore, flowers of *F. glareosa* might be the only available nutritional source for insect herbivores in that period. Considering the huge difference in fruit set of Type 1 and Type 2 patches (more than tenfold), it can be simply stated that the inflorescences of individuals in Type 1 patches were easily visible to *O. caucasicus* and therefore they were severely exposed to herbivorous attacks. In other words, the insect herbivores were considered to have an important role in the decline of fruit/seed set of individuals growing in Type 1 patches.

Population-level effects of insect herbivory are of potentially critical importance in the context of rare plant conservation and as a result, a major goal for the study of insect-plant interactions should be to understand when (for what species, at what times or places, or under what ecological conditions) insect herbivory drives plant population dynamics and when it does not [4, 8, 9]. The individuals growing in Type 1 patches provide almost no seed for their population in the years when the insect herbivory is in its peak level. The individuals in Type 2 patches (especially the short ones with little visibility to herbivores) keep on providing seeds abundantly for their populations even in such years when the species severely experiences a decline in their fruit/seed set (Figure 7). Because the primary aim of managing wild populations is increasing the size of small populations [10], sowing seeds in Type 2 patches may help to increase the population sizes of *F. glareosa.*

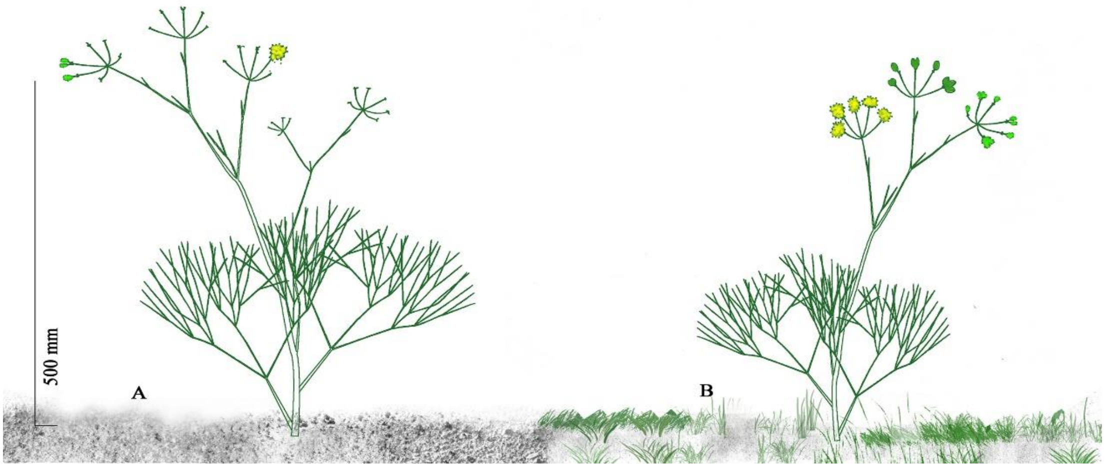

Figure 7. The illustration of fruit sets in Type 1 (A) and Type 2 patches (B)

Ignoring spatial variation can lead to undervalue potential herbivore impacts at local scales, which may determine micro distribution of a plant and thus restrict its regional population size [4]. If this study had been carried out without noticing the spatial variation in fruit set of individuals, our proposal for the possible conservation actions would have been for those in Type 1 habitats, such as introducing new individuals and/or sowing seeds to these patches. This action seems to have no positive impact on the survival of the species since there is extreme insect herbivory in these patches. Due to the extremely high spatial and temporal variance of the insect herbivory [11, 12], the studies on observing the visitors and the comparative studies between the habitat patches in terms of other population characteristics should be carried out before deciding any conservation action for *F. glareosa*. We wanted to draw attention to this issue since any new or even little information about conservation of endemic plants in Turkey is vital for their long-term survival in their natural habitats. The conservation actions to be implemented by ignoring these facts will hardly be successful.

It reveals that if the reproductive ecology data including insect herbivory are collected together with their spatial and/or temporal variation data during the conservation efforts for our endemic plant species with reduced reproductive success due to various reasons, the plant conservation actions can be planned using projections easily obtained from such preliminary or some detailed [13] surveys.

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