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# The selective consumption of European ivy (*Hedera helix*) berries by the Common Blackbird (*Turdus merula*)

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Seed dispersal of plants affects the spatial structure and population dynamics, contributing to ecosystem functioning. Birds are among the most important seed dispersers. Preferences of birds in fruit and berry consumption are potentially significant selective pressures on the evolution of fruit traits that affect plant fitness. European ivy (*Hedera helix*) is a widespread deciduous species in Europe and the Common Blackbird (*Turdus merula*) is important seed disperser. This study investigates blackbird feeding preferences for specific sizes of ivy seeds. Field data was collected in a small settlement east of Simferopol city in Crimea and included a collection of reference seeds gathered from plants and seeds found in bird excretions. The length of the major axis, minor axis, and aspect ratio were measured, and statistical analysis was performed. The length of the major and minor axes of seeds consumed by blackbirds was higher compared with the reference collection, the aspect ratio was the opposite. Evidence of size differences could suggest weak effect of selective consumption of blackbirds on seed shape. This research extends our knowledge of the ecological relationship between frugivorous birds and plants and the role of birds in directional selection in a particular locality.

## 1. Introduction

Seed dispersal is a vital process in the life cycle of plants because it influences the spatial structure, population dynamics, gene flow, and tree assembly and consequently, contributes substantially to ecosystem functioning (Levin *et al.* 2003, Flörchinger *et al.* 2010, Harrison *et al.* 2013, Hazell *et al.* 2023). Endozoochory is an example of seed dispersion when the diaspores of plants are eaten by animals and the hard seeds or fruit stones pass through the intestinal canal without damage (Smallwood 1984). Birds are the most important seed dispersers among temperate zone animals (Corlett 2017, Hazell *et al.* 2023). The preferences for fruit and berry consumption could exert selective pressure on the evolution of fruit traits, influencing plant fitness and the mutualistic interactions between fleshy-fruited plants and birds (Flörchinger *et al.* 2010, Eriksson 2016, Hazell *et al.* 2023).

European ivy (*Hedera helix*) has a southerly and westerly distribution in Europe from North Africa, with the nearest islands located in Western and South-Western Asia (Metcalfe 2005). Ivy berries are an important source of energy, containing 47% carbohydrates and 32% lipids relative to the dry weight of the pulp and providing just over 5 kcal per gram of dry pulp (Herrera 1987, Hernandez 2005). The Common Blackbird (*Turdus merula*) has a range that covers all of Europe and North Africa with the nearest islands located in Western and South-Western Asia (Collar & Christie 2020). At the end of twenty century, the species spread to the Steppe Zone of the Northern Black Sea region in response to the emergence of artificial plantings (Tsvelykh 2017, Kucherenko & Ivanovskaya 2020). Blackbirds are well known seed feeders (*i.e.* frugivores) (Williams 2006), making them perfect candidates for dispersing different plant species including ivy seeds (Snow & Snow 1988, Metcalfe 2005). Several researchers have reported that most fruit-eating birds consume only a portion of the diversity of fleshy fruits produced in any habitat (Snow 1981, Wheelwright 1985, Blendinger *et al.* 2016). Selective feeding of birds is one of the types of bird-plant interactions and play an essential role in the maintenance of biodiversity (Blendinger *et al.* 2012). However, the selection of different fruit traits by birds in different environments is poorly known (Hazel *et al.* 2023).

I hypothesized that if the influence of seed dispersers on a plant persists over a long time, the average seed size of the plant will correspond to the average seed size consumed by the primary dispersers. To unravel this hypothesis I assessed seed size selection by blackbirds at a particular ivy hedge site by comparing the size of seeds consumed by the birds to the average seed size on the trees. This may be important for establishing mutualistic interactions between birds and plants, functional diversity, conservation of endangered plant or bird species at the local level.

## 2. Material and methods

### 2.1. Study area

The study area is located in a small settlement east of Simferopol city (45°01'N, 34°11'E) in Crimea (the peninsula in the north of the Black Sea). The vegetation is mainly composed of poplar trees (*Populus alba*), sloe brush (*Prunus spinosa*) and dogrose (*Rosa canina*) growing alongside the small river, surrounded by arable fields and steppe patches. European ivy, which is typically found in mountain-forest landscapes 15–20 km south of the research locality, grows in a hedgerow at the study site. Ivy plants were planted in the study area more than 20 years ago from their natural habitat.

### 2.2. Data collection

In February, when the ivy berries were ripe and consumed by birds, I collected the seeds ($n=65$) that had been eaten with berries and excreted by blackbirds near the hedgerow edges. At the same time, the ivy berries which were on plants were gathered to get reference samples of available seeds. In the tree the ivy berries were arranged into umbels thus to ensure random sampling, I collected all berries from 10 umbels taken from various parts of four plants. The selected berries varied in size, and I removed only the very small and damaged ones. Then I collected the seeds ($n=96$) from these berries, assuming that they were medium berries and seeds of the plant. The pulp was removed and the seeds were sampled. Each berry contained one or two seeds.

All seeds were measured to obtain the length of the major axis (Fig. 1, see axis A), the length of the minor axis (Fig. 2, see axis a), and the aspect ratio (the ratio A/a). The seeds were flattened on one side, thus the minor axis was measured at the widest part. All measures were carried out by using a caliper. To determine the species of birds that consume ivy berries, I visually inspected plants and recorded all species visited the plants. According to the previous review, 15 bird species were documented as ivy berries consumers (Metcalfe 2005), thus I found out the phenology of their presence in the study area over the past 6 years.

### 2.3. Statistical analysis

To determine the normality of data Shapiro-Wilk test was used. To evaluate differences in length and aspect ratio of seeds that were eaten by birds, and seeds sampled in trees, the Mann-Whitney

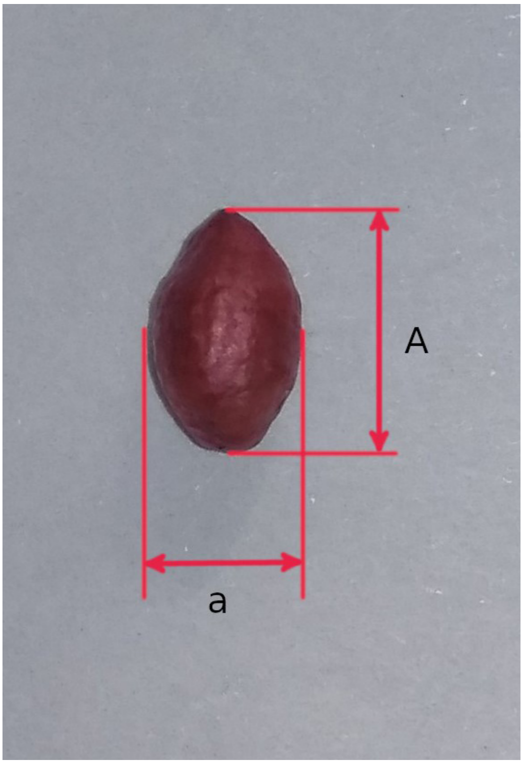


Fig. 1. The seed of European ivy (*Hedera helix*). A – length of major axis, a – length of the minor axis.

test was applied. I used the generalized linear regression model (GLM) with binomial error distribution (Zuur *et al.* 2007, Kabakoff 2014) to obtain the model of the probability of seed consumption by birds as a function of size and shape characteristics.

The predictors were major and minor length and aspect ratio (continuous variables), and the response variable was whether seeds were collected in plants or birds' excretions (categorical variable). The best model was chosen by comparing the full model and the model with removed predictors by computing analysis of variance fitted models (Chambers & Hastie 1992) with ANOVA. If the differences were nonsignificant, the model with the lowest AIC (Akaike information criterion) was chosen (Akaike 1998). All assumptions were checked before GLM was applied.

Statistical analyses were carried out in free open source software R version 4.2.3 (R Core Team 2024). To visualize the differences in the size and shape of consumed seeds and seeds gathered from plants the 'ggplot2' package was used (Wickham 2016). The model result was performed with the 'pROC' package (Robin *et al.* 2011). Model residual diagnostics were carried out with the 'DHARMa' package (Hartig 2022).

## 3. Results

There are four bird species recorded as ivy berry consumers in the study region: Common Woodpigeon (*Columba palumbus*), European Starling (*Sturnus vulgaris*), Eurasian Blackcap (*Sylvia atricapilla*), and Common Blackbird. The first three species were rare visitors, and only a few cases of berry consumption by them were recorded, while the last species was the main ivy berry consumer. During visual observation, a single bird consumed 1–17 berries per feeding visit, in contrast to starling and blackcap, which consumed 1–4 berries per feeding visit.

Based on the measuring of 65 seeds excreted by blackbirds and 96 reference seeds, significant differences were found between the length of the major axis (Mann-Whitney test, $p < 0.001$), length of the minor axis ($p < 0.001$), and aspect ratio ($p < 0.001$) of seeds, found in bird excretions compared to those collected from plants (Table 1, Fig. 2).

Table 1. Mean (± standard deviation, SD) of maximal length, width, and shape index of European ivy seeds.

| | N | Length of major axis (mean ± SD), mm | Length of minor axis (mean ± SD), mm | Aspect ratio (mean ± SD) |
|---|---|---|---|---|
| Seeds excreted by blackbirds | 65 | 6.32 ± 0.584 | 4.10 ± 0.342 | 1.55 ± 0.153 |
| Seeds collected from plants | 96 | 5.69 ± 0.514 | 3.37 ± 0.425 | 1.71 ± 0.213 |

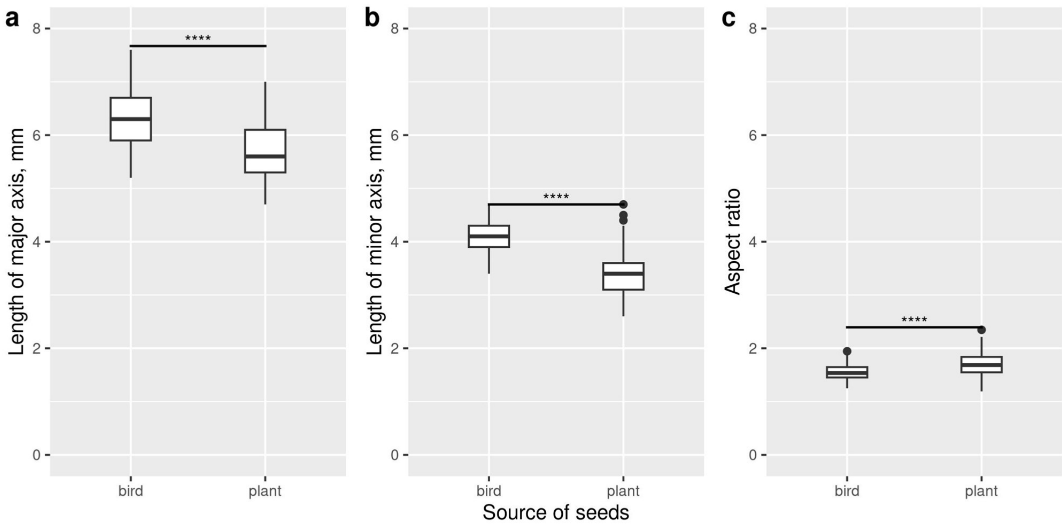


Fig. 2. Box plots representing the differences in length of major axis (a), minor axis (b) and aspect ratio (c) values between seeds found in blackbird excretions ("bird") and sampled from plants ("plant"). **** – $p < 0.001$.

The GLM results demonstrate that all predictors, except for the length of the minor axis, significantly influence the probability of seeds being consumed by birds (Supplementary Table S1, Supplementary Fig. S1). There was a positive relationship between the length of the major axis and seed consumption, whereas the length of the minor axis had a negative relationship. The model without the length of the minor axis did not differ significantly from the full model but had higher AIC. The model results suggest that blackbirds prefer berries with longer and rounder seeds.

## 4. Discussion

Previous studies have documented 15 bird species as consumers of ivy berries (Metcalfe 2005), whereas our study recorded only four. Most berries-feeding species are rare (*e.g.* Song Thrush *Turdus philomelos*, Waxwing *Bombycilla garrulus*), or absent (Capercaillie *Tetrao urogallus*) in the study region. Blackcap and Song Thrush are only present in spring, when blackbirds have already consumed most of the berries. Five species—Collared Dove (*Streptopelia decaocto*), Corn Bunting (*Emberiza calandra*), Robin (*Erithacus rubecula*), Fieldfare (*Turdus pilaris*), and Mistle Thrush (*T. viscivorus*)—were relatively abundant in the region to the time ivy are ripening, but I did not record their eating the ivy. It can be assumed that evidence of ivy consumption by other bird species depends on the availability of other food resources and the amount of ivy (Hernandez 2009). Only a few ivy plants grow in the study area, therefore not many birds could have used it.

In earlier research, the number of berries, consumed by blackbirds per feeding visit was $1.3 \pm 0.14$ (Sorensen 1984), while in this study the observed consumption ranged from 1 to 17 berries per feeding visit. A possible explanation for this result might be fewer disturbance factors in my location compared with Oxford Botanic Garden, where data were collected previously. The crowds of people that are typical of a botanical garden are a strong disturbance factor for birds. The place where my material was collected was sparsely populated and there was little disturbance to the birds. It is well known that some species forage less when people are nearby (Megan 2008).

As mentioned in the literature review, a major challenge in evolutionary ecology is to understand how mutualistic interactions between plants and animals drive the evolution of plant phenotype (Strauss & Irwin 2004, Palacio & Ordano 2018). Although gape width is a known limiting factor for fruit consumption (Wheelwright 1985, Bulgarini & Fraticalli 2023), the size of ivy berries aligns well with the gape size of blackbirds, allowing them to consume these fruits effectively. The current study found predominating long and rounded seeds in blackbirds' excretions compared with the reference seeds. In some plants, a correlation is often observed between berry volume and seed volume (Bulgarini & Fraticelli 2023). Despite this I did not find such information regarding ivy, it is possible that the size of berries eaten by birds was greater than the average size on plants.

One type of behaviour that facilitated selective feeding by tropical birds was based less on choosing fruits with appropriate size than on indiscriminating plucking fruits and being unable to swallow large ones (Wheelwright 1985). In contrast to these observations, data of feeding blackbirds by European Laurel (*Laurus nobilis*) suggests that birds search for berries on specific specimens or carefully select among the available berries on the branches, prioritizing those with rare shapes and sizes for consumption (Bulgarini & Fraticalli 2023). During the observation, there were many berries on the ground under the ivy, but I did not record any instances of small berries being picked or dropped.

The difference in seed size may be result of weak effect of selective consumption of blackbirds on seed shape, or indicate a additional factors whose action is stronger than the action of selection by the blackbirds. It is also possible that in the natural habitat of ivy, a different selective process occurs than the one we have observed. Some authors have emphasized the food specialization of individual birds in natural conditions (Grant 1981, Price 1987, Jung 1992). It is possible, that the preference for feeding by certain berry sizes by the local population of blackbirds differs from the sizes consumed by birds in the natural ivy habitats. From this point of view, future studies should explore seed dispersal in natural ivy populations to compare selection criteria for seed dispersal across different environments.

**Mustarastaan (*Turdus merula*) valikoiva muratin (*Hedera helix*) marjojen syönti**

Kasvien siementen leviäminen vaikuttaa merkittävästi ympäristön rakenteeseen, kasvipopulaatioiden dynamiikkaan ja ekosysteemien toimintaan. Linnut ovat keskeisiä siementen levittäjiä, ja niiden mieltymykset hedelmien ja marjojen suhteen voivat luoda valintapaineita hedelmien ominaisuuksille, mikä puolestaan vaikuttaa kasvien kelpoisuuteen ja ominaisuuksien evoluutioon.

Euroopan muratti (*Hedera helix*) on laajalle levinnyt kasvilaji Euroopassa, ja mustarastas (*Turdus merula*) toimii sen tärkeänä siementen levittäjänä. Tässä tutkimuksessa tarkasteltiin mustarastaan ravintomieltymyksiä erityisesti muratin siementen kokoon liittyen. Aineisto kerättiin Simferopolin kaupungin itäpuolella Krimillä sijaitsevasta pienestä asutuksesta, ja siihen sisältyi sekä kasveista kerättyjä vertailusiemeniä että lintujen ulosteista löydettyjä siemeniä. Siementen pää- ja sivuakselin pituudet sekä muotosuhteet mitattiin, ja tulokset analysoitiin tilastollisesti.

Tulokset osoittivat, että mustarastaan syömien siementen pää- ja sivuakselin pituudet olivat suurempia kuin vertailusiementen, mutta niiden muotosuhde oli päinvastainen. Havaittujen kokoerojen perusteella voidaan päätellä, että mustarastaan valikoivalla syönnillä on vain vähäinen vaikutus siementen muotoon. Tämä tutkimus syventää ymmärrystä hedelmiä syövien lintujen ja kasvien välisestä ekologisesta vuorovaikutuksesta sekä lintujen roolista kasvien ominaisuuksien evoluutiossa tietyssä ympäristössä.

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**Online supplementary material**

Supplementary material available in the online version of the article (https://doi.org/10.51812/of.148001) includes Figure S1 and Table S1.