The European laurel *Laurus nobilis* berries in the diet of the blackbird *Turdus merula*

Fabrizio Bulgarini, Fulvio Fraticelli*

Abstract - The feeding activity of frugivorous birds is influenced by the selection criteria for berry size. European laurel (*Laurus nobilis*), a dioecious species with high lipid and protein content in its berries, is dispersed by blackbird (*Turdus merula*). This study aimed to investigate the relationship between berry size and feeding behavior of blackbird. Field data was collected in a botanical park near Rome (Italy) and included seed collection, observation of regurgitation events, and bird population surveys. The volume and shape index of berries and seeds were measured, and statistical analyses were performed. The results showed a positive linear correlation between berry and seed volume. Blackbird selectively consumed larger berries, resulting in a higher percentage of pericarp as an energy resource. The birds exhibited a bimodal strategy, feeding on both large ellipsoidal and large round berries, which had a higher percentage of pericarp. The shape index of berries and seeds showed a significant difference between the control collection and those consumed by blackbird. The findings suggest a case of coevolution, with the plant optimizing seed dispersal by offering berries of different sizes to accommodate the feeding behavior of blackbird. This study provides insights into the ecological relationship between frugivorous birds and plants, highlighting the role of berry size in seed dispersal strategies.

Keywords: berry size and shape, trophic selection, coevolution.

Riassunto - Le bacche dell'alloro europeo *Laurus nobilis* nella dieta del merlo *Turdus merula*.

L'attività alimentare degli uccelli frugivori è influenzata dai criteri di selezione per la dimensione delle bacche. L'alloro europeo (Laurus nobilis), specie dioica con un alto contenuto lipidico e proteico nelle bacche, viene disperso dal merlo (Turdus merula). Questo studio mira a indagare la relazione tra la dimensione della bacca e il comportamento alimentare del merlo. I dati sul campo sono stati raccolti in un parco botanico presso Roma, inclusa la raccolta dei semi, l'osservazione degli eventi di rigurgito e le indagini sulla popolazione. Sono stati misurati il volume e l'indice di forma di bacche e semi e i dati sono stati sottoposti ad analisi statistiche. I risultati hanno mostrato una correlazione lineare positiva tra il volume dell'intera bacca e quello del seme. I merli consumavano selettivamente bacche più grandi, ottenendo una percentuale maggiore di pericarpo come risorsa energetica. Gli uccelli hanno mostrato una strategia bimodale, nutrendosi sia di grandi bacche ellissoidali che di grandi bacche rotonde, che avevano una percentuale maggiore di pericarpo. L'indice di forma delle bacche e dei semi ha mostrato una differenza significativa tra la raccolta di controllo e quella consumata dai merli. I risultati suggeriscono un caso di coevoluzione, con la pianta che ottimizza la dispersione dei semi offrendo bacche di diverse dimensioni per adattarsi al comportamento alimentare del merlo. Questo studio fornisce approfondimenti sulla relazione ecologica tra uccelli frugivori e piante, evidenziando il ruolo della dimensione delle bacche nelle strategie di dispersione dei semi.

Parole chiave: dimensione e forma delle bacche, selezione trofica, coevoluzione.

Stazione Romana per l'Osservazione e la Protezione degli Uccelli (SROPU), Piazza Margana 40, 00186 Roma, Italia.

* Corresponding author: f_fraticelli@hotmail.com

Received for publication: 25 May 2023
Accepted for publication: 30 August 2023
Online publication: 9 November 2023

INTRODUCTION

The selection criteria for berry size can influence the feeding activity of frugivorous birds (Howe & Vande Kerckhove, 1979; Herrera, 1981a; Calvario & Fraticelli, 1986; Fuzessy *et al*., 2018; Almazán-Núñez *et al*., 2021*;* Messeder *et al*., 2022). Birds also select berries based on their size and in relation to their ingesting capacity (Herrera, 1984). For plants, it is advantageous to have larger seeds dispersed (Bidwell, 1978), which are theoretically present within larger berries, due to their higher germinative capacity (Silvertown, 1981; Westoby *et al.*, 1992; Kidson & Westoby, 2000; Tumpa *et al.*, 2021). At the same time, plants will offer birds berries that contain a greater amount of pulp; this phenomenon can be interpreted as a case of coevolution (Ricklefs, 1981). European laurel (*Laurus nobilis*), the only native representative of the Lauraceae family, is a dioecious species, generally with a shrubby habit, but which can also assume a tree-like habit, reaching heights of up to 10 m. It is present in all Italian regions, although it is probably only native to Sicily, Sardinia, the Tuscan Archipelago, Zannone Island, Capri, and perhaps also in Maremma and along the Lazio coasts (Pignatti, 1982; Filibeck, 2006). European laurel, along with mastic (*Pistacia lentiscus*) and terebinth (*P. terebintus*), is one of the Mediterranean species with the highest percentage of lipids (54.3%) and proteins in the pulp of the berries (Herrera, 1982, 1987). The blackbird (*Turdus merula*) is a widely distributed resident and migratory breeding species in Italy (Brichetti & Fracasso, 2022), and has a high percentage of berries in its diet (Hartley, 1954; Snow, 1958; Simms, 1978; Herrera, 1981b; Snow & Snow, 1988; Théry, 1989; Soler *et al.*, 1991; Pesotskaya *et al.*, 2020). The blackbird plays a crucial role in the dispersal of Euro-

pean laurel seeds (Hampe, 2003), as evidenced by observations in an urban park in Rome, where the berries of this plant are one of their preferred foods (Sorace, 1990). The blackbirds regurgitate the seeds, thus preventing them from passing through the digestive system, which contributes to the successful dispersal of the species. This strategy, employed by all major thrush species only with plant species that have large seeds (Sorensen, 1981; Snow, 1987), is energetically advantageous as it allows for greater assimilation of the pulp (Snow, 1971; McKey, 1975; Howe & Vande Kerckhove, 1980; Herrera, 1981c; Sorensen, 1984; Levey & Grajal, 1991; Murray *et al.*, 1993), although this has been challenged (Witmer, 1998).

MATHERIALS AND METHODS

Study area

The study area was located within the WWF Natural Oasis "Bosco di Palo" (Ladispoli, Rome, 41°56' N-12°05' E), in a botanical park that is now in a state of abandonment. There are introduced tree species present in the area: *Cupressus glabra, C. macrocarpa, Pinus pinaster, P. pinea, P. halepensis, Washingtonia filifera, Chamaerops humilis, Phoenix canariensis*. The native tree and shrub species, in addition to European laurel, are: *Quercus pubescens, Q. ilex, Ulmus minor, Arbutus unedo, Phillyrea angustifolia, P. latifolia, Mirtus communis, Pistacia lentiscus, Rubus ulmifolius, Viburnus tinus, Fraxinus angustifolia* subs. *oxycarpa, F. ornus, Crataegus monogyna, Rhamnus alaternus, Prunus spinosa, Rosa sempervirens, Pyrus spinosa*. European laurel is very abundant, and some individuals reach 10 m in height with trunks of about 40 cm in diameter.

Dataset field data collection

From October 1991 to January 1992, the season during which mature berries were present on European laurel plants, we collected 223 seeds of this plant from the soil along 100 m dirt road that were regularly frequented by blackbird during their feeding activity. Prior to this collection, we thoroughly removed any pre-existing seeds from the soil. In the study area, several bird species were identified as potential consumers of European laurel berries, including the blackcap (*Sylvia atricapilla*), which regularly feeds on these berries, albeit at a much lower percentage compared to the blackbird, as observed in Spain (Hampe, 2003). Other species that can potentially feed on these berries are the European starling (*Sturnus vulgaris*) and the song thrush (*Turdus philomelos*). However, the first species always frequents dense vegetation, while the other two frequent open areas; therefore, the seeds collected along dirt roads could be reasonably attributed to berries eaten by blackbirds. To increase the level of certainty that the collected seeds were actually regurgitated by blackbirds, we conducted a series of observation sessions throughout the data collection period for a total of 24 hours, during which we confirmed our initial hypothesis; direct observations were made of regurgitation in 34 instances during brief pauses by individuals who were likely foraging for arthropods in the surrounding terrain. To quantify the population of blackbirds, present in the study area, we repeated an 800 m transect twice a month using the method proposed by Ferry & Frochot (1958). Furthermore, we randomly collected 312 European laurel berries directly from both large and small plants (n 17) at various heights from the ground and within a 20 m strip from the ecotone. Using a precision caliper of 0.1 mm, we measured the major and minor axes of the berries, their seeds after removing the pericarp, and the regurgitated seeds of blackbirds, and calculated their volume by assuming them to be ellipsoids. We also calculated the shape index for both the berry and the seeds by applying the formula $(A / a) \times 100$, where A represents the major axis (from the attachment of the stem to the opposite apex) and a represents the minor axis. A value of 100 indicates a perfectly spherical berry. For statistical analysis of the data, we used the Pearson correlation coefficient, two-tailed Mann-Whitney U test and Kolmogorov-Smirnov test of normality with a significance level of $\alpha < 0.05$.

RESULTS

The value of the Kilometric Abundance Index (KAI) for the blackbird varied from 30 to 15 individuals, with a peak in October coinciding with post-breeding migration (Spina & Volponi, 2008). These KAI values are higher than those found in similar Mediterranean environments (Farina, 1982; Jordano, 1985; Sorace, 2000; Trotta, 2010) probably due to the abundance of trophic resources.

The values of the entire berry volume in the sample collection show a normal distribution (Kolmogorov-Smirnov Test $p = 0.31$) and a potentially symmetrical skewness shape (Fig. 1).

In the sample collection (Tab. 1) there is a statistically significant positive linear correlation between the volume of the berry and seed ($R = 0.84$; $P < 0.001$). The values of the shape index in the sample collection do not show a normal distribution (Kolmogorov-Smirnov Test $p = 0.02$) and a potentially symmetrical skewness shape (Fig. 2). We did not find a statistically significant correlation between the volume of the entire berry and the shape index ($R = 0.10$; $P = 0.09$). There is no statistically significant correlation between the shape index and the volume of the pericarp ($R = 0.09$; $P = 0.13$), but obviously rounder berries have a higher percentage of pulp ($R = 0.48$: $P <$

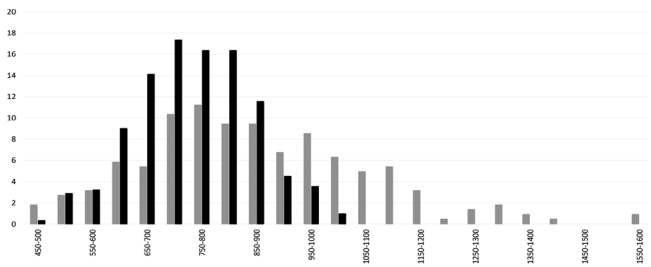

Fig. 1 - Percentage of volumes (mm³) of laurel berries in the sample collection (black columns) and theoretical volumes of those consumed by the blackbird (grey columns) represented with a 50 mm³ interval. / Percentuale di volumi (mm³) di bacche di alloro nel campione di confronto (colonne nere) e volumi teorici di quelle consumate dal merlo (colonne grigie) rappresentati con un intervallo di 50 mm³.

Tab. 1 - Mean of volume, shape index and volume of pericarp (± Standard Deviation) of berries and seeds of European laurel in the sample collection and regurgitated by blackbirds. Volumes expressed in mm³; the theoretical values are in italics. / Media del volume, dell'indice di forma e del volume del pericarpo (± deviazione standard) delle bacche e dei semi di alloro europeo presenti nel campione di confronto e rigurgitati dai merli. Volumi espressi in mm³; i valori teorici sono in corsivo.

	N	Volume of berries	Volume of seeds	Shape index of berries	Shape index of seeds	Volume of pericarp
Sample collection	312	768.93 ± 107.26	513.23 ± 90.78	87.14 ± 3.63	88.53 ± 3.62	255.70 ± 24.82
Regurgitated by blackbirds	216	*876.79 ± 206.30*	589.03 ± 145.85	*82.63 ± 9.11*	86.29 ± 5.55	*287.75 ± 7.29*

0.001). Using the existing correlation between the volume of the entire berry and that of the seed in the sample collection we were able to estimate the theoretical volume of berries consumed by the blackbird from the volume of regurgitated seeds (Tab. 1). These values show a normal distribution (Kolmogorov-Smirnov Test $p = 0.01$), but potentially asymmetric skewness shape (Fig. 1). Since we found a statistically highly significant difference (z-score = -6.05; P < 0.001 Mann-Whitney U test) between the mean volume of seeds in the reference sample and those consumed by the blackbird, we also found a statistically highly significant difference (z-score = -6.20; P < 0.001 Mann-Whitney U test) between the mean volume of berries in the collected sample and the theoretical volume of those consumed by the blackbird. Consequently, there is also a statistically highly significant difference between the mean volume of the pericarp of the berries in the sample collection and the theoretical volume of the berries consumed by the blackbird (z-score = -5.80; P < 0.001 Mann-Whitney U test). Furthermore, since there is a statistically highly significant positive linear correlation (R = 0.57; P < 0.001) between the shape index of the berry and the shape index of the seed in the sample collection, we were able to calculate the theoretical shape index of the berries consumed by the blackbird from the shape index of the regurgitated seeds. We excluded seven data points from the analysis that exceeded a value of 100 due to the level of approximation in the processing. This was done because the value exceeded that of a perfectly spherical berry and because they were identified as outliers in the Kolmogorov-Smirnov test. The values do not show a normal distribution (Kolmogorov-Smirnov Test $p = 0.02$), a potentially symmetrical skewness shape and an apparent bimodal distribution (Fig. 2). Berries with a more rounded shape eaten by blackbirds, with shape index values greater than 80 (n = 132), which represent 63 % of the diet, showed a volume of 891.00 ± 224.51 mm³, while those in the sample collection, also with shape index values greater than 80 (n = 306), which represent 98 % of the sample, had a volume of 769.41 ± 106.65 mm³; there was a statistically highly significant difference between these two volumes (z-score = -5.28; P < 0.001 Mann-Whitney U test). The berries with a more elongated shape eaten by blackbirds, with shape index values less than 80 (n = 89), which represent 47 % of the diet had a volume of 855.78 ± 175.08 mm³, while those in the sample collection, also with shape index values less than 80, were only five, however, this volume is statically larger compared to that of all the berries in the sample collection (z-score = -4.48; P < 0.001 Mann-Whitney U test).

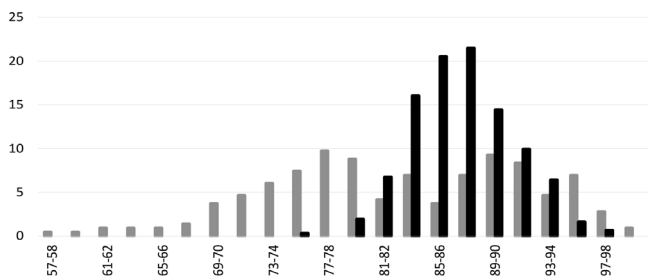

Fig. 2 - Percentage of the shape index values of the laurel berries in the sample collection (black columns) and the theoretical shape index of those eaten by the blackbird (grey columns). / Percentuale dei valori dell'indice di forma delle bacche di alloro del campione di confronto (colonne nere) e dell'indice di forma teorico di quelle mangiate dal merlo (colonne grigie).

There is a statistically highly significant difference (z-score = 4.85; P < 0.001 Mann-Whitney U test) between the mean shape index of the seeds contained in the berries of the sample collection and that of the seeds in the berries eaten by the blackbird, as well as between the mean shape index of the berries in the control collection and the theoretical index of those eaten by the blackbird (z-score = 5.67; P < 0.001 Mann-Whitney U test).

DISCUSSION AND CONCLUSIONS

The blackbird exhibits a selective preference for larger berries in its diet, as well as measurements that were absent in the comparison sample, approximately 12% larger; consequently, it has a higher quantity of pericarp as an energy resource. In the selection of berry shape, the blackbird apparently employs a bimodal strategy, feeding on both large ellipsoidal berries, absent in the comparison sample, and large round berries, which, at equal volume, possess a higher percentage of pericarp compared to the others. By selecting ellipsoidal berries, the blackbird is able to ingest those with a larger volume in relation to its mouth width which, according to Herrera (1984), measures 13.4 mm. However, by considering the seed size, in four instances, the berries consumed by the blackbird should have had both axes of the entire berry exceeding the value reported by Herrera (1984), up to 14.4 mm. The blackbird, however, like other bird species (Wheelwright, 1985), also feeds on small-sized berries. Consequently, there is significant variability in the sizes of the dispersed seeds, which require the removal of the pericarp for germination (Sari *et al*., 2006). In conclusion, the observed

data suggests that the blackbird searches for berries on specific European laurel specimens, which were not sampled in our study and probably rare, or carefully selects among the available berries on the branches, prioritizing those with rare shapes and sizes for consumption. The observed phenomenon could be interpreted as a case of coevolution, allowing the plant to optimize its resources by increasing the chances of dispersal, as observed in other species (Howe & Vande Kerckhove, 1981; Mason *et al.*, 2022), with larger seeds being more suitable for producing propagules in areas with strong competition from other plants, while smaller seeds are more suited to playing a role as colonizers (Foster & Janson, 1985).

Acknowledgements

We sincerely thank Corrado Battisti and Giuliano Fanelli for the critical review of the text.

REFERENCES

Almazán-Núñez R. C., Alvarez-Alvarez E. A., Sierra-Morales P. & Rodríguez-Godínez R., 2021 – Fruit size and structure of zoochorous trees: Identifying drivers for the foraging preferences of fruit-eating birds in a Mexican successional dry forest. *Animals*, 11 (12), 3343. <https://doi.org/10.3390/ani11123343>

Bidwell R. G. S., 1978 – Fisiologia vegetale. *Piccin Editore*, Padova.

Brichetti P. & Fracasso G., 2022 – The birds of Italy. 3 Cisticolidae - Icteridae. *Edizioni Belvedere*, Latina.

Calvario E. & Fraticelli F., 1986 – *Rubia peregrina* berries in the winter food of Robins *Erithacus rubecula*. *Avocetta,* 10 (2-3): 115-118.

Farina A., 1982 – Bird community of Mediterranean Forest of Migliarino (Pisa - Central Italy). *Avocetta*, 6 (2): 75-81.

Ferry C. & Frochot B., 1958 – Une méthode pour dénombrer les oiseaux nicheurs. *Revue d'Écologie - La Terre et la Vie*, 2: 85-102.

Filibeck G., 2006 – Notes on the distribution of *Laurus nobilis L.* (Lauraceae) in Italy. *Webbia*, 61 (1): 45-56.

Foster S. A. & Janson C. H., 1985 – The relationship between seed size and establishment conditions in tropical woody plants. *Ecology*, 66 (3): 773-780.

Fuzessy L. F., Janson C. & Silveira F. A., 2018 – Effects of seed size and frugivory degree on dispersal by Neotropical frugivores. *Acta Oecologica*, 93: 41-47.

Hampe A., 2003 – Frugivory in European Laurel: how extinct seed dispersers have been substituted. *Bird Study*, 50 (3): 280-284.

Hartley P. H. T., 1954 – Wild fruits in the diet of British thrushes. A study in the ecology of closely allied species. *British Birds*, 47 (1): 97-107.

Herrera C. M., 1981a – Fruit variation and competition for dispersers in natural populations of *Smilax aspera*. *Oikos*, 36 (1): 51-58.

Herrera C. M., 1981b – Datos sobre la dieta frugívora del Mirlo (*Turdus merula*) en dos localidades del sur de España. *Doñana*, *Acta Vertebrata*, 8: 306-310.

Herrera C. M., 1981c – Are tropical fruits more rewarding to dispersers than temperate ones? *American Naturalist*, 118 (6): 896-907.

Herrera C. M., 1982 – Seasonal variation in the quality of fruits and diffuse coevolution between plants and avian dispersers. *Ecology*, 63 (3): 773-785.

Herrera C. M., 1984 – Adaptation to frugivory of Mediterranean avian seed dispersers. *Ecology*, 65 (2): 609-617.

Herrera C. M., 1987 – Vertebrate-dispersed plants of the Iberian Peninsula: a study of fruit characteristics. *Ecological Monographs*, 57 (4): 305-331.

Howe H. F. & Vande Kerckhove G. A., 1979 – Fecundity and seed dispersal of a tropical tree. *Ecology*, 60 (1): 180-189.

Howe H. F. & Vande Kerckhove G. A., 1980 – Nutmeg dispersal by tropical birds. *Science*, 210 (4472): 925-927.

Howe H. F. & Vande Kerckhove G. A., 1981 – Removal of Wild Nutmeg (*Virola surinamensis*) crops by birds. *Ecology*, 62 (4): 1093-1106.

Jordano P., 1985 – El ciclo annual de los Passeriformes frugívoros en el matorral mediterráneo del sur de España: importancia de su invernada y variaciones interanuales. *Ardeola*, 32 (1): 69-94.

Kidson R. & Westoby M., 2000 – Seed mass and seedling dimensions in relation to seedling establishment. *Oecologia*, 125 (1): 11-17.

Levey D. J. & Grajal A., 1991 – Evolutionary implications of fruit-processing limitations in Cedar Waxwings. *American Naturalist*, 138 (1): 171-189.

Mason D. S., Baruzzi C. & Lashley M. A., 2022 – Passive directed dispersal of plants by animals. *Biological Reviews*, 97 (5): 1908-1929.

McKey D., 1975 – The ecology of coevolved seed dispersal systems. In: Coevolution of animals and plants. Gilbert L. E. & Raven P. H. (eds.). *University of Texas Press*: 159-191.

Messeder J. V. S., Guerra T. J., Pizo M. A., Blendinger P. G. & Silveira F. A. O., 2022 – Seed dispersal ecology in neotropical Melastomataceae. In: Systematics, evolution, and ecology of Melastomataceae. Goldenberg R., Michelangeli F. A. & Almeda F. (eds). *Springer*: 735-759.

Murray K. G., Winnet-Murray K., Cromie E. A., Minor M. & Meyers E., 1993 – The influence of seed packaging and fruit color on feeding preferences of American Robins. *Vegetatio*, 107/108: 217-226.

Pesotskaya V. V, Chaplygina A. B., Shupova T. V. & Kratenko R. I., 2020 – Fruit and berry plants of forest belts as a factor of species diversity of ornithofauna during the breeding season and autumn migration period. *Biosystems Diversity*, 28 (3): 290-297.

Pignatti S., 1982 – Flora d'Italia. *Edagricole*, Bologna.

Ricklefs R. E., 1981 – Ecologia. *Zanichelli*, Bologna.

Sari A. O., Oguz B. & Bilgic A., 2006 – Breaking seed dormancy of laurel (*Laurus nobilis* L.). *New Forestes*, 31 (3): 403-408.

Silvertown J. W., 1981 –Seed size, life span, and germination date as coadapted features of plant life history. *American Naturalist*, 118 (6): 860-864.

Simms E., 1978 – British Thrushes. *Collins*, London.

Snow B. & Snow D. W., 1988 – Birds and berries. *Poyser*, Calton.

Snow D. W., 1958 – A study of Blackbirds. *George Allen & Unwin,* London.

Snow D. W., 1971 – Evolutionary aspects of fruit-eating in birds. *Ibis*, 113 (2): 194-202.

Snow D. W., 1987 – The Blackbird. *Shire Natural History*, 13.

Soler M., Pérez-Gonzales A. & Soler J. J., 1991 – Regimen alimenticio del Mirlo comun (*Turdus merula*) en el sureste de la peninsula Iberica durante el periodo otoño-invierno. *Doñana, Acta Vertebrata*, 18 (1): 133-148.

Sorace A., 1990 – Aspetti della nicchia trofica del Merlo *Turdus merula* in un parco urbano. *Avocetta*, 14 (2): 119-128.

Sorace A., 2000 – L'avifauna svernante nella Riserva WWF di Monte Arcosu (Sardegna). *Rivista italiana di Ornitologia*, 70 (2): 149-158.

Sorensen A. E., 1981 – Interactions between birds and fruit in a temperate woodland. *Oecologia*, 50: 242-249.

Sorensen A. E., 1984 – Nutrition, energy and passage time: experiments with fruit preference in European Blackbirds *Turdus merula*. *Journal of Animal Ecology*, 53 (2): 545-557.

Spina F. & Volponi S., 2008 – Atlante della migrazione degli uccelli in Italia. 2. Passeriformi. *Ministero dell'Ambiente e della Tutela del Territorio e del Mare, Istituto Superiore per la Protezione e la Ricerca Ambientale (ISPRA)*, Roma.

Théry M., 1989 – Consommation des fruits et dissémination des graines par le merle noir (*Turdus merula* L.) en zone périurbaine sous climat tempéré. *Acta Oecologica, Oecologia Applicata*, 10: 271-285.

Trotta M., 2010 – Le comunità ornitiche svernanti nelle formazioni boschive della riserva naturale di Decima-Malafede: analisi del biennio 2009-2010. *Alula*, 17 (1-2): 1-9.

Tumpa K., Vidaković A., Drvodelić D., Šango M., Idžojtić M., Perković I. & Poljak I., 2021 – The effect of seed size on germination and seedling growth in sweet chestnut (*Castanea sativa* Mill.). *Forests*, 12 (7), 858. <https://doi.org/10.3390/f12070858>

Westoby M., Jurado E. & Lishman M., 1992 – Comparative evolutionary ecology of seed size. *Tree*, 7 (11): 368-372.

Wheelwright N. T., 1985 – Fruit size, gape width, and the diets of fruit-eating birds. *Ecology*, 66 (3): 808-818.

Witmer M. C., 1998 – Do seeds hinder digestive processing of fruit pulp? Implications for plant/frugivore mutualisms. *Auk*, 115 (2): 319-326.