

ORIGINAL PAPER

# Food trees and fecundity of forest cockchafer *Melolontha hippocastani* Fabr.

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## ABSTRACT

The forest cockchafer *Melolontha hippocastani* Fabr., is a significant forest pest in Europe; food tree quality is limiting for the fecundity of its females. Laboratory experiments with breeding adults were conducted after their hibernation, with each individual offered leaves from 20 tree species. The weight of adults and production of eggs in relation to food were studied in the first oviposition. Food trees affected the fecundity and the frequency of egg-laying females very positively (*Quercus petraea*, *Larix decidua*, *Acer pseudoplatanus*, *Populus nigra*), significantly (*Q. rubra*, *Aesculus hippocastanum*, *Carpinus betulus*, *Sorbus aucuparia*, *Malus* sp.), non-significantly (*Betula pendula*, *Fagus sylvestris*, *Corylus avellana*, *Juglans regia*, *Populus tremula*). *Tilia cordata*, *Sambucus nigra*, and *Robinia pseudoacacia* exhibited no influence on egg laying. Food tree species during breeding positively affected the increasing weight of females feeding on *Q. petraea*, *Q. rubra*, *P. nigra*, *P. tremula*, *C. betulus*, *A. hippocastanum*, and *S. aucuparia*.

## KEY WORDS

*Acer*, *Aesculus*, *Carpinus*, *Corylus*, fecundity, food, *Larix*, *Populus*, *Quercus*, *Sorbus*

## Introduction

Forest cockchafer *Melolontha hippocastani* Fabr., a scarabaeid beetle, is a significant phytophagous pest in Europe, with a development cycle of 3-5 years (Hůrka, 1955; Bulmer, 1977; Christensen, 1986; Vestergaard *et al.*, 2000; Sierpińska, 2008; Švestka, 2012). Adults eat leaves of both fruit and forest trees. Woody plants used by cockchafer for maturation while feeding in natural conditions have been characterized and specified since the end of the 19<sup>th</sup> century (Erichson, 1848; Taschenberg, 1874; Nördlinger, 1882; Henschel, 1895; Feddersen, 1896; Boden, 1896; Zweigelt, 1928; *etc.*). Grubs develop in the soil where they feed on the root systems of trees and cultivated plants. Imagines hibernate in the ground and lay eggs in the soil in spring after maturation feeding (Kula, 2021).

After the hibernation, adults restore, through maturation feeding, the supply of fat that is limiting for the formation of eggs (Keller *et al.*, 1995; Wagenhoff *et al.*, 2014). During oogenesis, females reduce flying and concentrate on nutrition, while their weight grows as the eggs are formed (Wheeler, 1996). The weight of males does not change during maturation feeding, which is rather a source of energy for mating and flying. Although the imagoes use a wide range

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of broadleaved tree species for their maturation feeding, opinions differ with respect to their associations with *M. hippocastani* and *M. melolontha* (L.) (Taschenberg, 1874; Nördlinger, 1882; Henschel, 1895; Feddersen, 1896; Boden, 1896; Bothe, 1899; *etc.*). The choice of woody plant strongly depends on the phenology of budding, morphological characteristics and age of leaves, as well as on the flight phase of the beetles (Escherich, 1923; Sachtleben, 1926; Zweigelt, 1928; Malinowski, 2008).

The size of females, population density of imagines, weather during the formation of eggs, and nutritional value of the food of females have differential influences on life span and fertility (Woreta *et al.*, 2016). Therefore, the number of eggs recorded in ovaries after the first and second maturation feedings differs (Schneider, 1952; Vogel, 1955; Wagenhoff *et al.*, 2014).

*Melolontha hippocastani* positively responds to *Quercus petraea* (Matt.) Liebl. and *Q. robur* L., while *M. melolontha* prefers *Fagus sylvatica* L. and *Larix decidua* Mill. but does not lay eggs after feeding on *Betula pendula* Roth. The species *Carpinus betulus* L. and *Sorbus aucuparia* L. contribute to low fertility (Woreta and Sukovata, 2010; Woreta *et al.*, 2016). *Alnus glutinosa* (L.) Gaertn., *Sambucus nigra* L., *Prunus serotina* Ehrh., *Robinia pseudoacacia* L., *Tilia* sp., and *Pyrus* sp. have negative impacts on both vitality and fertility (Taschenberg, 1874; Kittel, 1879; Nördlinger, 1882; Zweigelt, 1928; Sierpiński, 1975; Woreta and Sukovata, 2010).

The goal of this research was to clarify the relationships of the imagoes of forest cockchafer to a range of food trees and the influence of the food trees on the fecundity of females and life span of imagoes under laboratory conditions.

## Material and methods

In the laboratory breeding experiments, hibernating imagines of *M. hippocastani* from Bzenec locality (48°56.808' N, 17°15.831' E) were used that were unfed and left in the sand at a temperature of 5-7°C prior to being included in the breeding. Breeding containers made of plastic material (180×180×105 mm) were provided with ventilation holes (diam. 6 mm) below the upper edge and covered with a cap. The container bottom was covered with a ~30-40 mm deep layer of sand, giving the females a natural environment for laying eggs. In an earlier study, Woreta and Sukovata (2010) left the females to lay eggs in the breeding containers freely without the substrate. There were 1♀ and 1♂ in each breeding container, with 15 repetitions for each woody plant.

The fertility and life span in breeding forest cockchafers were studied in relation to 20 tree species (*Acer pseudoplatanus* L., *Aesculus hippocastanum* L., *B. pendula*, *C. betulus*, *Corylus avellana* L., *F. sylvatica*, *Juglans regia* L., *L. decidua*, *Malus* sp., *Populus nigra* L., *P. tremula* L., *Prunus* sp., *Pyrus* sp., *Q. petraea*, *Q. rubra* L., *R. pseudoacacia*, *S. aucuparia*, *S. nigra*, *Rubus fruticosus* L., and *Tilia cordata* Mill.).

The twigs and leaves were collected from trees growing in the locality of Brno – Hády (GPS: 49°13'40", 16°41'30"), or in the campus of Mendel University in Brno (Černá pole, GPS: 49°12'42", 16°37'03") at the time of control. A twig with leaves, the number of which was modified according to their size, was inserted into the breeding box in a container with water. Water was added as needed during the control, and new twigs with leaves were put in.

The imagoes were inspected and weighed upon their entering the experiment, and then at intervals of three to four days with an accuracy of 0.001 g (analytical scales – Ohaus Adventurer Pro Analytical AV 2101 Balance Ohaus Corporation Greifensee, Switzerland).

During the control, dead males were replaced immediately, dead females only after verification that they had not laid eggs in the sand. The exact number of eggs deposited into the

sand was determined after 2-3 weeks when their handling did not jeopardize the oncoming hatching.

The breeding experiments were conducted during two periods (10 April – 20 June 2016, 40 days and 29 April – 31 May 2019, 33 days) at a laboratory temperature ranging from 20-22°C.

Laying frequency was expressed as the number of laying females out of the total number of females in the breeding.

Data were statistically evaluated using one-way ANOVA ( $H=f(\text{Loc})$ ), mean  $\pm$  confidence interval, Tukey HSD Test,  $\alpha=0.05$ , in Statistica 13 (TIBCO Software Inc. 2018). In the results, the calculated significance level ( $p$ ) is reported and compared with the selected  $\alpha$ .

## Results

**FOOD TREE EFFECT ON THE WEIGHT OF FEMALES.** The increase of average weight in females feeding on *Q. petraea* in a normal way exhibited a statistically significant dependence [F(5, 72)=6.1967,  $p=0.0001$ ], with the weight increasing from the beginning of the breeding experiment (0.477 g) to the culmination (days 10-13) by 37% (0.654-0.657 g) (Fig. 1a). The weight of females feeding on *Q. rubra* increased by 30%.

Fed leaves of *P. nigra*, females showed a continual weight increase peaking at 36% and then falling to a mean weight of 0.496 g (dead females), but with no statistical significance [F(8, 92)=2.559,  $p=0.0145$ ] (Fig. 1c). Weight increase in females feeding on *P. tremula* peaked at 20%.

*S. aucuparia*: the average weight of females peaked between days 7-18 (0.542-0.752 g), increasing significantly by up to 39% [F(10, 115)=3.1109,  $p=0.0015$ ].

Females feeding on the leaves of *C. betulus* exhibited a slightly increasing but not significant [F(10, 121)=2.049,  $p=0.0339$ ] average weight up to the peak at 0.725 g, or 39% (Fig. 1f).

In spite of the fact that *A. hippocastanum* is not a common forest tree, females accepted the food, and after a decrease of average weight in the first week of the breeding experiment (0.552 g) they exhibited a nearly continual, but not significant increase up to 0.706 g (+28%) [F(10, 98)=2.283,  $p=0.0189$ ] (Fig. 1e).

Females feeding on the needles of *L. decidua* responded positively by increasing weight (0.609-0.664 g) [F(8, 118)=1.5065,  $p=0.1621$ ]; weight loss did not occur until after their death (0.535 g) (Fig. 1d).

At the beginning of the breeding experiment with *A. pseudoplatanus*, the average weight of females decreased by 10%, and the maximum weight reached only the initial level [F(8, 115)=3.122,  $p=0.0031$ ] (Fig. 2a).

In the breeding experiment with the leaves of *Prunus* sp., no statistical significance [F(8, 96)=2.613,  $p=0.0124$ ] was recorded in the average weight of females. After a decrease (-20%, 0.531 g) and a subsequent increase in mean weight peaking at 0.681 g (+28%), females did not lay eggs (Fig. 2b).

Feeding on the leaves of *Malus* sp. caused an average weight loss of 15% in females; further on, the weight was relatively balanced [F(8, 111)=1.426,  $p=0.1935$ ] (Fig. 2c).

The average weight of females feeding on the leaves of *C. avellana* decreased non-significantly (17%) at the beginning of the breeding experiment [F(8, 115)=2.420,  $p=0.0188$ ] (0.689-0.573 g), but some females increased their weight in the second half of the experiment (13%) (Fig. 2d).

*T. cordata* was not accepted by females in the breeding experiment, and their average weight continually decreased significantly to the mortality level of 0.403 g [F(4, 69)=14.22,  $p<0.0001$ ] (Fig. 1b). A similar weight loss was recorded in females feeding on *Sambucus nigra*.

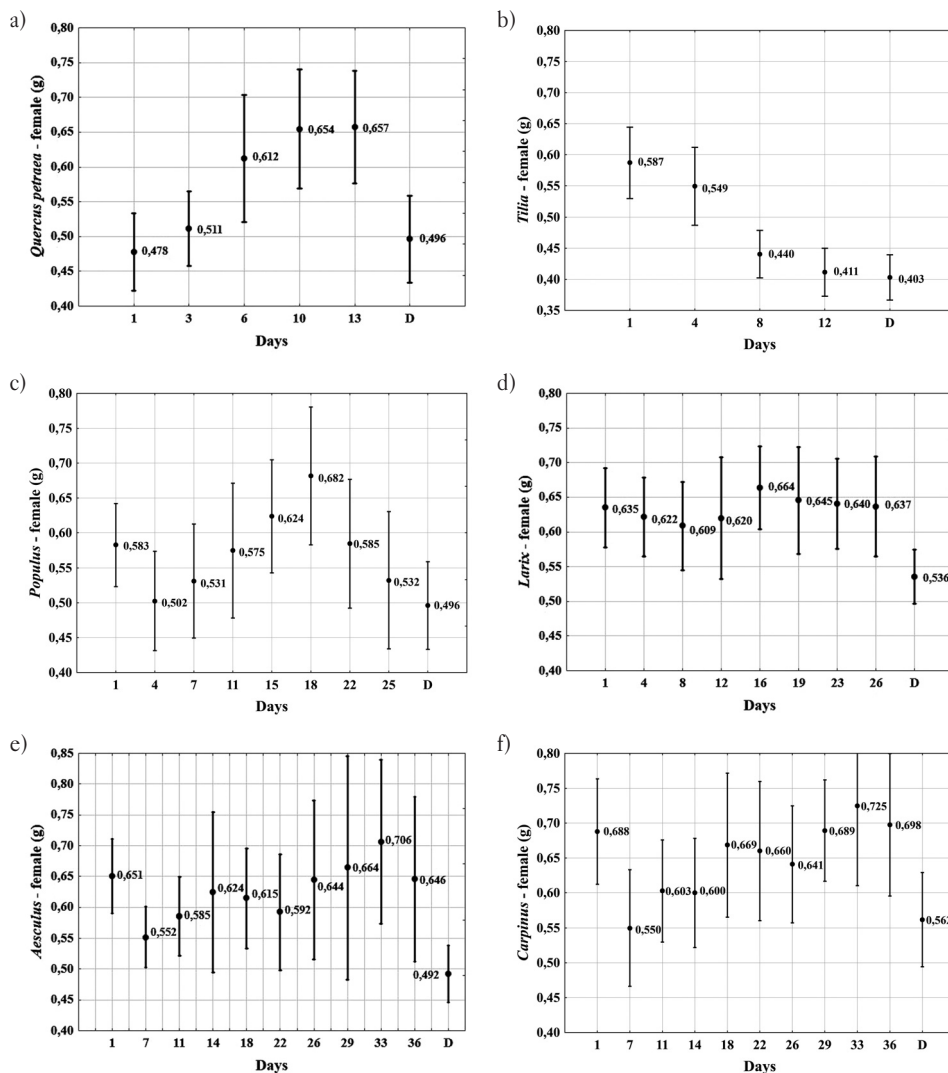


Fig. 1.

Weight of *Melolontha hippocastani* females in laboratory breeding on various nutrient tree species (*Quercus petraea*, *Tilia*, *Populus*, *Larix*, *Aesculus*, *Carpinus*) (2016)

Despite some partial deviations, the weight of females feeding on the leaves of *F. sylvatica* exhibited a continual gradual decrease (28%) with a significant dependence [F(9, 113)=2.993,  $p=0.0031$ ] (Fig. 2f).

*B. pendula* is a species on which imagoes only bite off leaves in petioles, which are then left to lie on the ground surface without any other damage. The average weight of females gradually decreased over the course of the experiment, with no significant dependence [F(8, 99)=1.937,  $p=0.0627$ ] (Fig. 2c).

Females that fed on the leaves of *R. pseudoacacia*, *Pyrus* sp. and *Rubus* sp. did not exhibit any significant response in the change of weight.

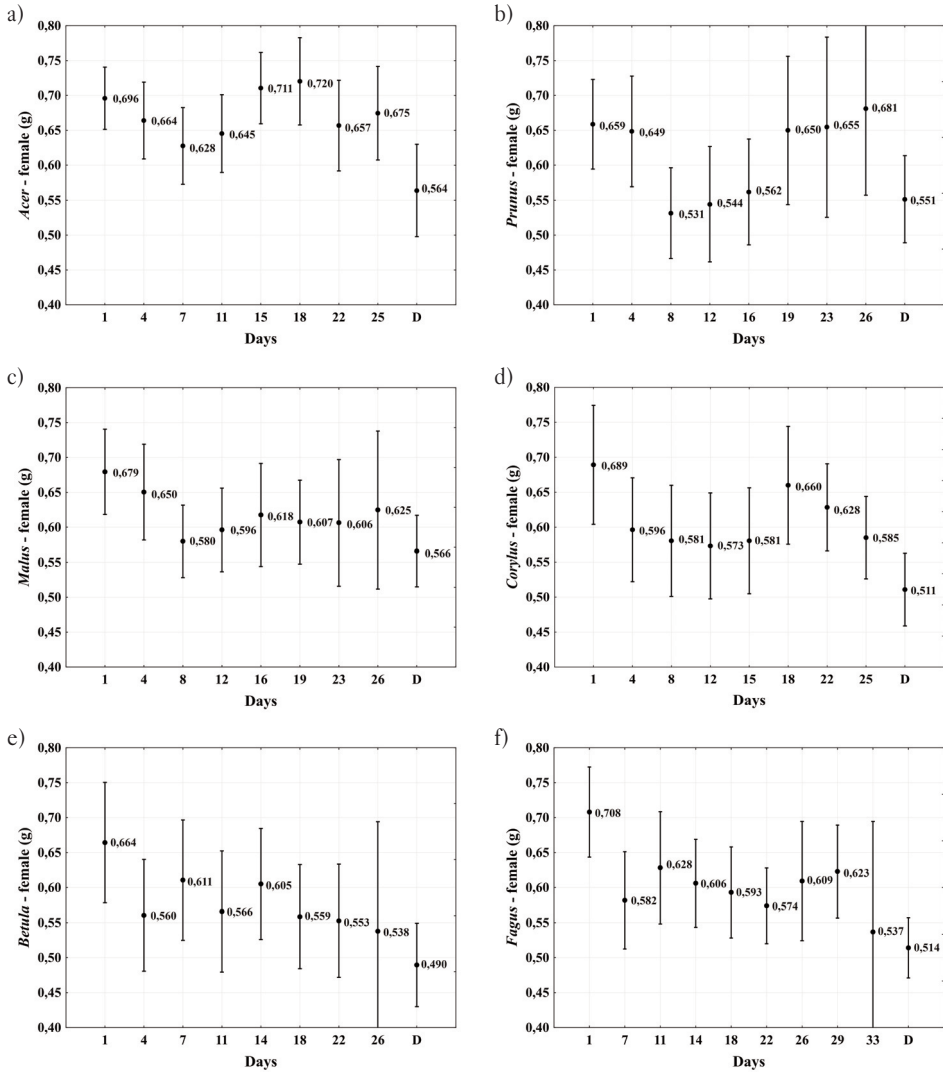


Fig. 2.

Weight of *Melolontha hippocastani* females in laboratory breeding on various nutrient tree species (*Acer*, *Prunus*, *Malus*, *Corylus*, *Betula*, *Fagus*) (2016)

FOOD TREE EFFECTS ON FERTILITY. In females, the first egg laying was assessed after they fed on *Q. robur*, *L. decidua*, *P. nigra*, and *A. pseudoplatanus*, reaching 16.6-17.9 eggs/female; 80-86.6% of females laid eggs in the breeding experiment. As a source of food, *P. tremula* was accepted with a high average number of eggs laid (16.5 eggs/female), but with a low percentage of laying females (13.3%). Females which fed on *Malus* sp., *A. hippocastanum* and *Q. rubra* leaves laid on average 12.4-15.8 eggs/female, but there was a lower number of laying females (46.6-66.6%). *C. betulus* appeared to be a rather interesting tree species; although 93.3% of females laid eggs, the total average number of eggs laid was low (7 eggs/female). In the repeated breeding experiment, the average number of eggs laid was higher (14.6 eggs/female), but the number of egg-laying females decreased (33.3%). Feeding on the leaves of *S. aucuparia*, up to 60% of females

laid eggs but the average number of eggs was low (8.3 eggs/female). As to tree species commonly affected by the feeding of beetles in natural conditions (*F. sylvatica*, *B. pendula*, *R. pseudoacacia*), a very low production of eggs was observed in the breeding experiments (0–4 eggs/female) as well as a low percentage of egg laying females (0–26.6%). Average egg laying was identical in females feeding on *C. avellana*, *P. avium*, and *J. regia* (8.3–9 eggs/female), but with varying proportions of egg laying females (6.6–26.6%). The unattractiveness of the leaves of *T. cordata* and *S. nigra* for the forest cockchafer was confirmed (Table 1).

**FOOD TREE EFFECT ON THE VITALITY OF IMAGOS.** The life span of the imagoes of forest cockchafer in the breeding experiments was affected by the type of food tree. In general, males exhibited higher mortality and a significantly shorter average time of remaining in the experiments as compared with females feeding on the same food source (e.g., *Acer*, *Betula*, *Carpinus*, *Corylus*, *Fagus*) [F(13, 718)=3.035,  $p=0.0002$ ] (Fig. 3). Identical average survival times were recorded in females and males feeding on *Aesculus*, *Juglans*, *Populus*, *Prunus*, *Sorbus*, and *Tilia* (Fig. 3). The longest average survival of females in the experiments was recorded when they were feeding on *Larix*, *Malus*, *Carpinus*, and *Corylus*. Females and males survived for a very short time if they were offered *Tilia* and *Juglans*; the same was observed in males feeding on *Quercus*. The average number of days of male survival (14–19) was lower than in females (25–31) (Fig. 3).

## Discussion

The significance of food sources for the development of such a wide range of polyphagous cockchafers has been studied only to a limited extent so far (Woreta and Sukovata, 2010; Wagenhoff *et al.*, 2014; Woreta *et al.*, 2016, 2018).

The weight of *M. hippocastani* adults increased when they were feeding on oak (37.3%), hornbeam (20.7%), birch (14.2%), and alder (4.2%) (Woreta and Sukovata, 2010).

From the range of trees studied, we confirmed weight increase in females feeding on both *Q. petraea* (37.4%) and *Q. rubra* (30.1%). The efficiency of food was also recorded in females feeding on *P. tremula* (20.6%), *P. nigra* (36%) and *S. aucuparia* (39%). There may not be a relationship between food quality and time spent in the breeding experiment. If there is no alternative source of food in the experiment, low nutritional value can cause reduced food intake, block the formation of eggs, and even lead to death (Woreta *et al.*, 2018). Some woody plants are mentioned as unattractive to chafers or little sought by them such as alder (Rożyński, 1926; Sierpiński, 1975), pear (Kittel, 1879), lime (Golubev, 1976), or black locust (Zweigelt, 1928). We have demonstrated in laboratory breeding that some tree species (e.g., *B. pendula*, *F. sylvatica*), which are heavily damaged by cockchafers in the forest, do not have an effect on egg production.

In this respect, *B. pendula* was confirmed as an inappropriate source of food. Nevertheless, it is attacked by forest cockchafer as it is one of the earliest-budding tree species. The behaviour of cockchafers is specific – they only bite the leaves off in the petiole, which then fall undamaged onto the ground. The same behavior was observed in the laboratory experiment when all leaves from the offered twig were bitten off without any further damage by feeding, and females mostly failed to lay eggs (average 0.5 egg/female). Unlike Nunberg (1934), other authors (Sierpiński *et al.*, 1975; Woreta *et al.*, 2018) consider the nutritional value of birch to be low. The reason can be the birch-specific biologically active substances (Polakowska, 1982; Kosiński and Krzystak-Kosińska, 2008). Birch leaves contain flavonoids, which function as natural insecticides and fungicides, and together with glycosides are highly toxic to insects (Nowak, 2011; Woreta *et al.* 2018).

Table 1.  
Influence of nutrient tree species on fecundity of *Melolontha hippocastani* females

| Tree species                  | Duration of breeding females (males) | Number of laying females | Frequency [%] | Sum of eggs | The average number of eggs per clutch | Maximum clutch | Average fertility in breeding |
|-------------------------------|--------------------------------------|--------------------------|---------------|-------------|---------------------------------------|----------------|-------------------------------|
| 2016                          |                                      |                          |               |             |                                       |                |                               |
| <i>Quercus petraea</i>        | 3 V-3 VI (30 V)                      | 13                       | 86.7          | 232         | 17.8                                  | 31             | 15.5                          |
| <i>Larix decidua</i>          | 20 IV-6 VI (28 V)                    | 13                       | 86.7          | 229         | 17.6                                  | 41             | 15.3                          |
| <i>Acer pseudoplatanus</i>    | 21 IV-6 VI (30 V)                    | 13                       | 86.7          | 216         | 16.2                                  | 28             | 14.4                          |
| <i>Populus nigra</i>          | 21 IV-3 VI (28 V)                    | 12                       | 80.0          | 206         | 17.2                                  | 32             | 13.7                          |
| <i>Aesculus hippocastanum</i> | 10 IV-6 VI (6 VI)                    | 10                       | 66.7          | 124         | 12.4                                  | 21             | 8.3                           |
| <i>Carpinus betulus</i>       | 10 IV-9 VI (28 V)                    | 14                       | 93.3          | 98          | 7.0                                   | 18             | 6.5                           |
| <i>Malus</i> sp.              | 20 IV-20 VI (6 VI)                   | 7                        | 46.7          | 98          | 14.0                                  | 38             | 6.5                           |
| <i>Sorbus aucuparia</i>       | 10 IV-9 VI (28 V)                    | 9                        | 60.0          | 75          | 8.3                                   | 21             | 5.0                           |
| <i>Corylus avellana</i>       | 21 IV-6 VI (30 V)                    | 6                        | 40.0          | 56          | 9.3                                   | 30             | 3.7                           |
| <i>Juglans regia</i>          | 19 V-20 VI (11 VI)                   | 4                        | 26.7          | 35          | 8.7                                   | 20             | 2.3                           |
| <i>Fagus sylvatica</i>        | 10 IV-26 V (30 V)                    | 4                        | 26.7          | 11          | 2.7                                   | 4              | 0.7                           |
| <i>Betula pendula</i>         | 10 IV-12 VI (22 V)                   | 2                        | 13.3          | 8           | 4.0                                   | 7              | 0.5                           |
| <i>Prunus avium</i>           | 20 IV-6 VI (9 VI)                    | 1                        | 6.7           | 9           | 9.0                                   | 9              | 0.6                           |
| <i>Tilia cordata</i>          | 20 IV-28 V (28 V)                    | 0                        | 0.0           | 0           | 0.0                                   | 0              | 0.0                           |
| 2019                          |                                      |                          |               |             |                                       |                |                               |
| <i>Quercus petraea</i>        | 29 IV-28 V (21 V)                    | 10                       | 66.7          | 181         | 18.1                                  | 27             | 12.1                          |
| <i>Quercus rubra</i>          | 29 IV-31 V (21 V)                    | 9                        | 60.0          | 142         | 15.8                                  | 28             | 9.5                           |
| <i>Carpinus betulus</i>       | 29 IV-28 V (28 V)                    | 5                        | 33.3          | 73          | 14.6                                  | 28             | 4.9                           |
| <i>Populus tremula</i>        | 29 IV-28 V (14 V)                    | 2                        | 13.3          | 33          | 16.5                                  | 29             | 2.2                           |
| <i>Pyrus</i> sp.              | 29 IV-28 V (14 V)                    | 1                        | 6.7           | 16          | 16.0                                  | 16             | 1.1                           |
| <i>Rubus</i> sp.              | 29 IV-28 V (14 V)                    | 1                        | 6.7           | 24          | 24.0                                  | 24             | 1.6                           |
| <i>Fagus sylvatica</i>        | 29 IV-28 V (14 V)                    | 0                        | 0.0           | 0           | 0.0                                   | 0              | 0.0                           |
| <i>Betula pendula</i>         | 29 IV-28 V (14 V)                    | 0                        | 0.0           | 0           | 0.0                                   | 0              | 0.0                           |
| <i>Sambucus nigra</i>         | 29 IV-14 V (14 V)                    | 0                        | 0.0           | 0           | 0.0                                   | 0              | 0.0                           |
| <i>Robinia pseudacacia</i>    | 29 IV-28 V (21 V)                    | 0                        | 0.0           | 0           | 0.0                                   | 0              | 0.0                           |

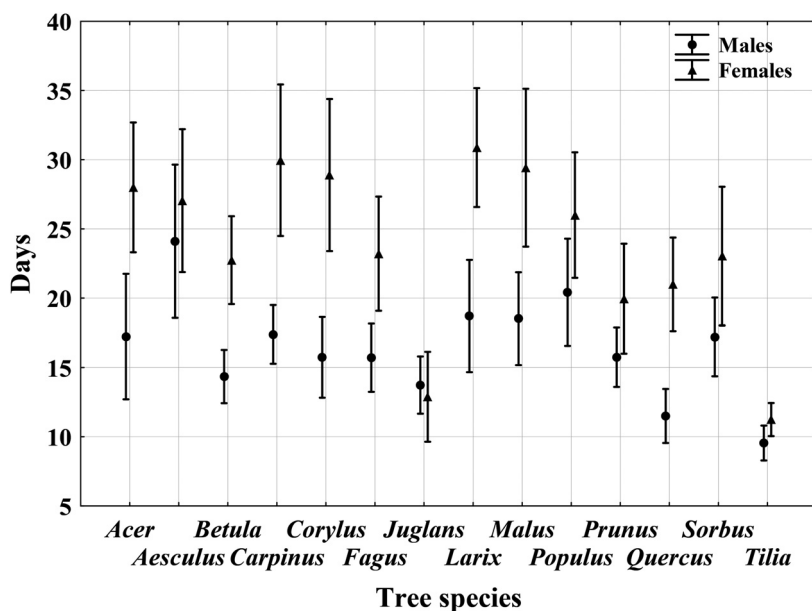


Fig. 3.

Influence of nutrient tree species on life span (number of days) of *Melolontha hippocastani* males and females in laboratory breeding

Birch is not the only tree species for which the forest cockchafer causes up to complete defoliation (beech, walnut, black locust, hazel) with a very low average number of eggs produced in the first egg deposition (0-3.7 eggs/female). A detailed chemical analysis that could determine differences in nutrition is missing.

Golubev (1976) describes the formation of eggs in females feeding on birch, trembling aspen, and mazzard cherry, while cockchafer feeding on lime, alder, sycamore maple, European mountain ash, and goat willow died within a week. These data cannot be corroborated by results of our breeding experiments, in which *A. pseudoplatanus* especially was one of the highly attractive trees according to laying frequency and the number of eggs laid. Woreta *et al.* (2016) evaluated *A. platanooides* positively as a source of food. Feeding on European mountain ash resulted in a low number of eggs laid, and the species is preferred by the forest cockchafer (Woreta *et al.*, 2016), with eggs being laid by 60% of females. The finding about the food unattractiveness and non-laying of eggs can be fully accepted in *Tilia*, *Alnus*, *Fraxinus*, *Viburnum*, and *Sambucus* (Woreta *et al.*, 2016) including *Pyrus*, *Rubus*, *Robinia*, *Fagus*, and *Betula*. Lime leaves contain (among other things) flavonoids, essential oils, tannins, and organic acids (Kosinski and Krzystak-Kosińska, 2008). These phytochemicals produce defence substances against herbivorous insects (Nowak, 2011).

Although the leaves of *F. sylvatica* are evaluated as nutritionally less favorable than the leaves of oak (Woreta *et al.*, 2016), feeding on beech was very intensive (Kula, 2021). The leaves contain organic acids (Podgórski and Podgórska, 2009) and flavonoid, which acts as a detergent protecting trees from infestation by insects (Harborne, 1997).

Tissues of *R. pseudoacacia* contain toxic organic acids, glycosides, and essential oils (Sarwa, 2001) but in varying concentrations in the plant organs (Bohne and Dietze, 2008). In spite of the fact that late budding and coming to leaf is limiting (a month later than hornbeam and 14 days



after the budding of oak), a forced concentrated feeding resulted in the defoliation of black locust when suitable food had been lost in the gradation area (Bzenec 2015) (Kula, 2021). In the laboratory breeding, feeding on the leaves of *Robinia* was corroborated but eggs were not laid.

In *A. glutinosa*, the observed negative effects on the vitality and fertility of cockchafer (Woreta and Sukovata, 2010) may be caused by repulsiveness and even toxicity of leaves to the beetles (Rożyński, 1926; Sierpiński, 1975) because they contain tannins, triterpenes, hyperoxides and essential oils (Podgórski and Podgórska, 2009). Yet there is a wide spectrum of phytophagous insects occurring on the alder, namely gradating chrysomelids: *Agelastica alni* (L.), *Linnaeidea aenea* (L.), and *Galerucella lineola* (F.) (Urban, 2007). The forest cockchafer occurred in the crowns of alders despite their late budding (Kula, 2021).

The high concentration of manganese in oak leaves adversely affects the food consumption as well as the fertility of forest cockchafer (Martinek *et al.*, 2018).

During the first egg laying, numbers of eggs >30 deposited by the females of forest cockchafer were sporadic even when they were feeding on the highly attractive and high-quality trees (oak, larch, apple, poplar). On this food, 80-87% of the females laid eggs during the first laying and their average fertility was 13.7-15.5 eggs. The breeding experiment with *M. hippocastani* on *Q. petraea* and *Q. rubra* fully corroborates the data published by Woreta *et al.* (2018) for *Q. robur* and *Q. rubra* as the most efficient sources of food. *Q. rubra* has the advantage of high capacity to regenerate its assimilatory organs after defoliation (Kula, 2021).

In breeding experiments with feeding on hornbeam, Woreta and Sukovata (2010) recorded only one egg-laying female (10%) of *M. hippocastani*, while *M. melolontha* accepted the hornbeam (Woreta *et al.*, 2016). In the breeding experiment with *M. hippocastani*, we observed up to 93% of egg-laying females, but their fertility was low (6.5 eggs/female). Hornbeam, which comes out 14 days earlier than oak (Hájková *et al.*, 2012) and immediately after the start of forest cockchafer swarming, represents the most significant food tree species affected by defoliation (Kula, 2021).

As to the nutritional quality, needles of larch could be compared with oak as to the frequency of egg laying and numbers of eggs, and according to Woreta *et al.* (2016), also, their effect on the life span and abundance of eggs laid by the females of both cockchafer species is positive. Anther flowers of pine represented food suitable only for *M. melolontha* (Woreta *et al.*, 2018), females of which then laid eggs. Pollen of pine contains sugars (33.7%), proteins, amino acids (23.9%), and cellulose (22.4%), water, fats, bio-elements, *etc.* (Kędzia, 2008). In the outbreak area of South Moravia with a 90% representation of *Pinus sylvestris*, intensive feeding of *M. hippocastani* on the anther flowers was observed after defoliation had occurred on *Q. rubra* (Kula *et al.*, 2015; Kula 2021). Unfortunately egg-laying capability was not verified in the breeding experiment.

In the breeding experiment, the life span of females was dependent on the food tree (oak, birch, hornbeam, alder = 23.6, 20.0, 19.3, 11.1 days, respectively) (Woreta and Sukovata, 2010). Female survival on *Quercus* in our study (20.8 days) agreed with those results, but greater female survival in the breeding experiment was recorded when they were feeding on *L. decidua*, *C. betulus*, *Malus* sp., *C. avellana*, and *A. pseudoplatanus* (28-31 days).

## Conclusions

The laboratory breeding experiments with the imagoes of forest cockchafer demonstrated that food sources, even those generally known and sought by the insects in natural conditions, have varying influences on the weight of females, their fertility and frequency of egg laying.

In natural conditions, *Melolontha hippocastani* causes defoliation of *Betula* and *Fagus*, but it was determined by laboratory breeding that these foods do not support the formation of eggs. *Carpinus betulus*, which sprouts earlier than *Quercus* sp., is a primary, very effective source of food supporting the formation of eggs. *Q. rubra* is a high-quality food source for *M. hippocastani*, and the assimilation apparatus recovers very quickly after defoliation. *Larix decidua*, although not significantly represented in the gradation areas of *M. hippocastani*, is an attractive food with a confirmed high laying frequency as well as number of eggs laid per female. Increases in the weight of females were influenced by high-quality food, but also by the production of eggs.

### Conflicts of interest

The author declare the absence of potential conflicts of interest.

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## STRESZCZENIE

### Drzewo żywicielskie a płodność chrabąszcza kasztanowca *Melolontha hippocastani* Fabr.

Chrabąszcz kasztanowiec to występujący w Europie ważny polifagiczny szkodnik, którego cykl rozwojowy trwa 3-5 lat. Dorosłe chrząszcze odżywiają się liśćmi drzew owocowych i leśnych, natomiast dla pędraków rozwijających się w glebie pokarm stanowią systemy korzeniowe drzew

i roślin uprawnych. Imagines hibernują w glebie, do której wiosną, po żerze uzupełniającym, składają jaja (Kula 2021).

Dotychczas znaczenie rodzaju pokarmu w procesie rozwoju tych polifagicznych chrabąszczy badano w ograniczonym zakresie (Woreta i Sukovata 2010; Wagenhoff i in. 2014; Woreta i in. 2016, 2018).

Celem pracy było wyjaśnienie relacji pokarmowych imagines chrabąszcza kasztanowca z różnymi gatunkami drzew, a także wpływu gatunku drzewa na rozrodczość samic i długość życia postaci dorosłych w warunkach laboratoryjnych.

W laboratoryjnym doświadczeniu hodowlanym wykorzystano hibernujące imagines *M. hippocastani*, które nie odbyły wcześniej żeru. Do hodowli użyto plastikowych pojemników, w których na dnie znajdowała się warstwa piachu o grubości około 30-40 mm, stwarzająca samicom naturalne środowisko do złożenia jaj. W każdym pojemniku hodowlanym znajdowały się 1 ♀ i 1 ♂ (15 powtórzeń na roślinę drzewiastą). Płodność i długość życia chrabąszczy w hodowli zbadano w odniesieniu do 20 gatunków drzew.

Imagines były kontrolowane i ważone na początku doświadczenia, a następnie w odstępkach 3 do 4 dni. Podczas kontroli martwe samce były natychmiast zastępowane żywymi, a martwe samice – dopiero po potwierdzeniu, że nie złożyły jaj w piasku. Doświadczenia były prowadzone od 10 kwietnia do 20 czerwca 2016 roku oraz od 29 kwietnia do 31 maja 2019 roku, w temperaturze laboratoryjnej 20-22°C.

Gatunek drzewa żywicielskiego pozytywnie wpłynął na wzrost wagi samic żywiących się *Quercus petraea* i *Q. rubra* (ryc. 1a), *Populus nigra* i *P. tremula* (ryc. 1b), *Carpinus betulus* (ryc. 1f), *Aesculus hippocastanum* (ryc. 1e) i *Sorbus aucuparia* (ryc. 1c). Masa chrząszczy utrzymywała się na stałym poziomie, gdy odżywiały się *Larix decidua* (ryc. 1d), *Robinia pseudoacacia*, *Pyrus* sp. i *Rubus* sp., a częściowy ubytek masy chrząszczy z późniejszym jej zbilansowaniem został odnotowany w przypadku samic żywiących się *Acer pseudoplatanus* (ryc. 2a), *Corylus avellana*, *Prunus* sp. i *Malus* sp. (ryc. 2b-d). Częściowa utrata masy została odnotowana u samic żywiących się *Fagus sylvatica* (ryc. 2f) i *Betula pendula* (ryc. 2e), natomiast postępująca utrata masy była obserwowana u samic, które w czasie trwania doświadczenia żywiły się *Tilia cordata* (ryc. 2g) i *Sambucus nigra*.

Gatunek drzewa żywicielskiego wpływał na płodność oraz liczbę składanych jaj bardzo pozytywnie (*Q. petraea*, *L. decidua*, *A. pseudoplatanus*, *P. nigra*), istotnie (*Q. rubra*, *Aesculus*, *C. betulus*, *S. aucuparia*, *Malus* sp.) lub nieistotnie (*Betula*, *Fagus*, *Corylus*, *Juglans*, *P. tremula*), natomiast samice, które odżywiały się *Tilia*, *S. nigra* i *R. pseudoacacia*, nie przystąpiły do składania jaj (tab. 1).

W doświadczeniu długość życia chrząszczy była zróżnicowana pomiędzy samcami a samicami, gdy żywiły się *Acer*, *Betula*, *Carpinus*, *Corylus*, *Fagus*, *Larix*, *Malus* i *Quercus*, natomiast równa, kiedy żywiły się *Malus*, *Aesculus*, *Juglans*, *Populus*, *Prunus* i *Tilia* (ryc. 3).

Stwierdzono, że waga samic wzrastała przy żerowaniu na *Q. petraea* (37,4%) (ryc. 1a), *Q. rubra* (30,1%), *P. tremula* (20,6%), *P. nigra* (36%) (ryc. 1b) oraz *S. aucuparia* (39%) (ryc. 1c). Potwierdzono, że *B. pendula* jest nieodpowiednim źródłem pokarmu. Zachowanie chrabąszczy jest specyficzne – nadgryzają jedynie ogonki liściowe brzozy, przez co nieuszkodzone blaszki liściowe opadają na ziemię. W laboratorium samice praktycznie nie składały jaj na brzozie (0,5 jaja/samicę). Dane dotyczące efektywności pokarmowej podawane przez Golubev (1976) nie znajdują pełnego potwierdzenia w niniejszych badaniach. Ze względu na częstotliwość składania jaj oraz ich liczbę *A. pseudoplatanus* należał do drzew wysoce atrakcyjnych. Także Woreta i in. (2016) pozytywnie oceniają *A. pseudoplatanus* jako źródło pokarmu. Samice żerujące na jesionie wyniosłym składały niewielką liczbę jaj, choć gatunek ten jest preferowany przez chrabąszcza kasztanowca (Woreta i in. 2016) – jaja składało 60% samic.

W doświadczeniach z żerowaniem na grabie Woreta i Sukovata (2010) odnotowały tylko jedną samicę *M. hippocastani* składającą jaja (10%), podczas gdy chrabąszcz majowy *M. melolontha* akceptował grab (Woreta i in. 2016). W doświadczeniu z *M. hippocastani* ustalono, że jaja składało do 93% badanych samic, chociaż ich płodność była niska ( $6,5 \pm 5,6$  jaja/samicę). W zakresie wartości odżywczych igły modrzewia są porównywalne z dębem zarówno pod względem częstotliwości składania jaj, jak i ich liczby, a według Worety i in. (2016) wpływają one pozytywnie również na długość życia oraz liczbę jaj składanych przez samice obu gatunków chrabąszczy.

Wyniki potwierdzają, że u *M. hippocastani* istnieje zależność pomiędzy pobieranym pokarmem (gatunek drzewa) a wysoką częstotliwością składania większej liczby jaj, jak również rozbieżność: wówczas, gdy po podaniu pokarmu z niektórych roślin drzewiastych jaja nie są składane lub są składane tylko sporadycznie.