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Effects of food source quality on the adults of *Melolontha melolontha* and *M. hippocastani*

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Abstract. This paper presents the results of studies on the life span, survival, weight and fecundity of the forest cockchafer (*Melolontha hippocastani*, Fabricius, 1801) and the common cockchafer (*Melolontha melolontha*, Linnaeus, 1758) beetle feeding on *Alnus glutinosa* (L.) Gaertn., *Betula pendula* Roth., *Carpinus betulus* L., *Fagus sylvatica* L., *Larix decidua* Mill., *Prunus serotina* (Ehr.) Borkh., *Quercus petraea* (Matt.) Liebl., *Quercus robur* L., *Robinia pseudoacacia* L., *Sambucus nigra* L. and *Sorbus aucuparia* L. em. Hedl. The lifespan and weight of beetles as well as female fertility were examined in 2011 and 2013. Specimen for laboratory tests were collected in the field shortly after leaving their overwintering sites in the soil and identical experimental protocols were applied to both examined species. 576 and 432 beetles were tested in 2011 and 2013, respectively. In 2011, beetles were feeding on *A. glutinosa*, *B. pendula*, *F. sylvatica*, *L. decidua Q. petraea* leaves and on *C. betulus*, *P. serotina*, *R. pseudoacacia*, *S. aucuparia* and *S. nigra* in 2013. Both years, beetles feeding on *Q. robur* leaves were examined as a control. Our results showed that feeding on leaves of *Q. robur* and *Q. petraea* had the largest positive impact on the life time, weight and fecundity of the studied beetles. Leaves of *F. sylvatica* and *L. decidua* also constituted an adequate food source for the development of *M. melolontha*. *M. hippocastani*, however, did not perform as well when feeding on these two tree species. Females of *M. melolontha* reared on leaves of *B. pendula* did not lay eggs. The following plant species had a negative impact on the survival and development of the collected specimen and female fertility: *A. glutinosa, S. nigra, P. serotina* and *R. pseudoacacia.* Neither beetle species fed on the leaves of *A. glutinosa* or *S. nigra.*

Keywords: forest cockchafer, common cockchafer, forest pests, relative growth rate, mortality, food quality

1. Introduction

Greater than before activity of the common cockchafer *Melolontha melolontha* (Linnaeus, 1758) as well as the forest cockchafer (*Melolontha hippocastani*, Fabricius, 1801) has been observed from the 1990s all over Europe (Zelger 1996; Brenner, Keller 1996; Strasser, Schinner 1996; Kronauer 2010; Švestka 2010), including Poland (Woreta 1995, 2015a). For quite a long time, both species have been a subject of interest of Poland's scientists (Karpiński 1950) and forest managers (Rożyński 1926) as the major insect pests in periodical years. Recently cockchafers have become a particular concern due to their long-lasting outbreak in European forests (Ott et al. 2006; Kronauer 2007, 2010). Above all, abundant cockchafer populations in the forest environment bring about severe damage to the crops.

Outbreak populations of cockchafer larvae (white grubs) seriously damage the roots of tree seedlings, which often leads to their death in forest nurseries and plantations. Furthermore, adult cockchafer beetles injure tree assimilation apparatus during their supplementary feeding in the canopy, hence, they decrease tree resilience and resistance to adverse environmental factors. In Poland, cockchafer beetles usually appear in May, and for two next months of the vegetation season, they feed in the crowns of deciduous trees, and at times – those coniferous (e.g. European larch). After swarming, females burry eggs deep in the soil. As soon as the first egg-masses are laid, females fly back to tree crowns and continue feeding. The majority of cockchafer females deposit eggs in the course of several days. Hatching larvae stay in the soil and start feeding on the roots of trees and brushes. White grub control is quite a huge task, so numerous different methods have been applied to decrease their populations in forests (Woreta 1997, 2015b).

As a result of ongoing cockchafer outbreak in Poland's forests, there occur the so called 'white grub permanent areas',

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i.e. the terrains where establishing any new forest plantation is relatively harder due to constant grub damage to the roots of planted seedling. On the whole, expanding cockchafer numbers have for years posed a threat both to young tree plantations and older deciduous stands. In consequence of the restrictions on the use of chemical pesticides (until recently, the only effective means to control the pest), there emerged an urgent need to identify new, non-chemical modes to control exceeding cockchafer populations. Consequently, the importance of biological, agro-technical and silviculture methods considerably increased in plant protection programs.

The purpose of the present study was to enhance knowledge on adult cockchafer biology and ecology, based on the evaluation of effects of diet on cockchafer body weight, survival and fecundity. Better understanding of cockchafer biology, including its food preferences can help elaborating better control strategies to protect forests against exceeding populations of this pest.

2. Material and Methods

2.1. Biological material

Biological material used in the study included:

- forest cockchafer *M. hippocastani* adults (collected in the Forest District (FD) Jabłonna in 2011 and FD Radom in 2013),
- common cockchafer *M. melolontha* adults (collected in FD Brzeziny in 2011 r. and FD Radom in 2013),
- leafy shoots of: silver birch *Betula pendula* Roth., common beech *Fagus sylvatica* L., black elder *Sambucus nigra* L., black cherry *Prunus serotina* (Ehr.) Borkh., sessile oak *Quercus petraea* (Matt.) Liebl., pedunculate oak *Quercus robur* L., common hornbeam *Carpinus betulus* L., rowan *Sorbus aucuparia* L. em. Hedl., European larch *Larix decidua* Mill., black alder *Alnus glutinosa* (L.) Gaertn. and false acacia *Robinia pseudoacacia* L., collected in FD Chojnów as food for adult cockchafers tested.

2.2. Methodology

The study was conducted in the years 2011 and 2013. Cockchafer adults were collected in the field, subsequently to their emergence after overwintering in the soil. The collection of insects was performed for the duration of one day, immediately after obtaining information from field observers about adult appearance. Further studies on cockchafer food preferences were carried out using the leaves of tree species growing in a given forest stand (including undergrowth). Taken as a whole, the leaves of 11 tree species were used in the study.

In 2011 (5 May–29 June), the assessments of effects of a given diet on cockchafer females and males were performed using the leaves of: silver birch, common beech, sessile oak, pedunculate oak, European larch and black alder. Altogether, 360 adult cockchafer beetles (180 specimens of forest cockchafer and 180 specimens of common cockchafer) were used for the assessments of life length and body weight gain. Tree shoots were kept in vials with water closed in glass containers covered with cotton mesh. In each container, there were placed 5 cockchafer females and 5 males. Each food treatment was repeated 3 times, i.e. 30 adult insects fed on the shoots of every tree species tested. The assessment of body weight gain was carried out 6 days after placing adults on food plants (5–11 May). All the tests on both cockchafer species were performed under glasshouse conditions.

In 2013 (30 April–12 July), the assessments of food effects included pedunculate oak as the control host plant as well as black elder, black cherry, common hornbeam, rowan and false acacia. Altogether, 216 adult cockchafer beetles (108 specimens of each cockchafer species examined). Host plant shoots fixed in vials with water were placed into glass containers covered with cotton mesh. In every container, there were put cockchafer 6 adults (3 females and 3 males). Each experimental variant was repeated 3 times, i.e. on the whole 18 adult insects fed on the shoots of a given tree species tested. The assessment of body weight gain in forest cockchafer adults were performed after 6 days of feeding (30.04–06.05), and in common cockchafer - after 7 days of feeding (13.05–20.05). The observations were conducted under open-field conditions.

In both observation years (2011 and 2013), tree shoots were replaced twice a week - then fresh water was added to the vials and cockchafer survival was monitored. Insect weight was determined to 0.001 g using a balance AD 300 (Axis Ltd., Gdańsk, Polska).

In 2011 and 2013, female fecundity was studied using in total 216 beetles (108 of each cockchafer species tested). First, females (4) and males (2) were placed into the glass containers - on the shoots of a given tree species tested (3 replications). After 11 and 10 days (2011 and 2013, respectively) of feeding together, from each treatment studied, there were randomly picked out 10 females and individually placed into new containers filled with sand (1/3 of container volume). Taking into account the fact that cockchafer females lay eggs in several-day intervals and feed in the meantime, the observed females were provided with food (leafy shoot of the tree species so far fed on - fixed in a vial with water). The shoots were replaced every 2 days. The numbers of laid eggs was assessed 3 weeks later.

2.3. Mathematical and statistical analyses

Adult weight changes were assessed based on relative growth rate (RGR), calculated in line with the following formula (Lazarevic et al. 2002):

$$RGR = \frac{(M_t - M_0)}{(T_{t-0} \times M_0)}$$

where:
M_o and M_t –initial and final insect weight (g),
T_{t-o} – the number of days between initial and final weight measurements.

It was assumed that adult feeding was most intense in the first week of insect culture, thus initial and final weight measurements were carried within the period of 6–7 days.

The differences of the mean RGR values obtained in adults feeding on different tree species were tested with the use of one-way ANOVA as well as one-way ANOVA on ranks (the Kruskal-Wallis non-parametric test).

The differences between the mean numbers of eggs laid by females of the examined cockchafer species feeding on different host plants were tested with the use of Tukey's HSD for equal sample sizes.

3. Results

3.1. Effects of different forest tree species on cockchafer life span, weight gain and fecundity

Life span

The results of the analyses carried out on forest cockchafer adults in 2011, showed that when compared to other host plants tested, males feeding on black alder leaves lived for the shortest time (2 weeks). On beech leaves, 100% mortality of males was observed after 4 weeks of feeding, and males feeding on other tested tree species lived 5 weeks (Fig. 1A). Forest cockchafer females lived comparatively the longest on European larch shoots (up to 7 weeks), whereas females feeding on black alder lived for the shortest period of time (3 weeks) (Fig. 1B).

Life span of common cockchafer males was also the shortest on black alder leaves – about 7 days (Fig. 2A), and on silver birch leaves, the observed males lived twice as long. The lon-

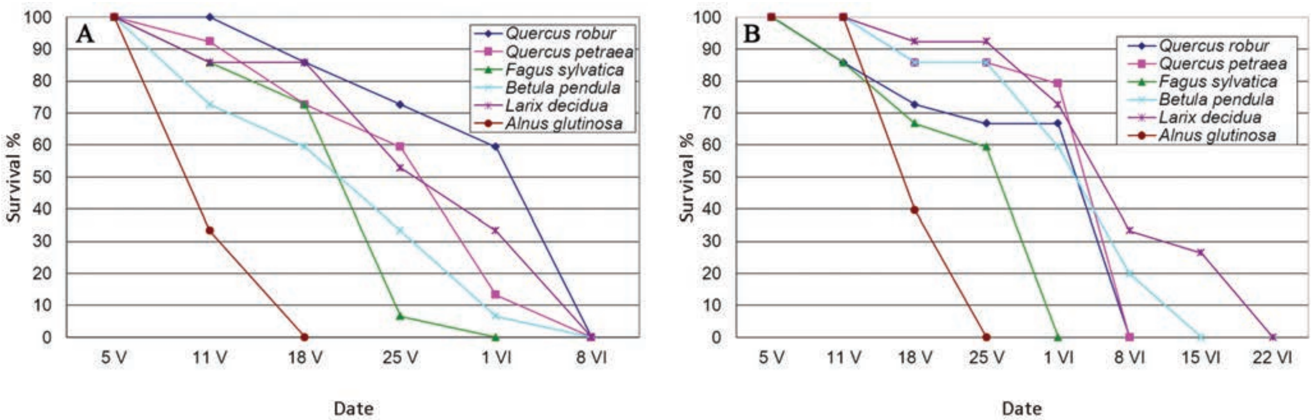


Figure 1. The survival of adult males (A) and females (B) of the forest cockchafer feeding on leaves of different tree species in the laboratory in 2011

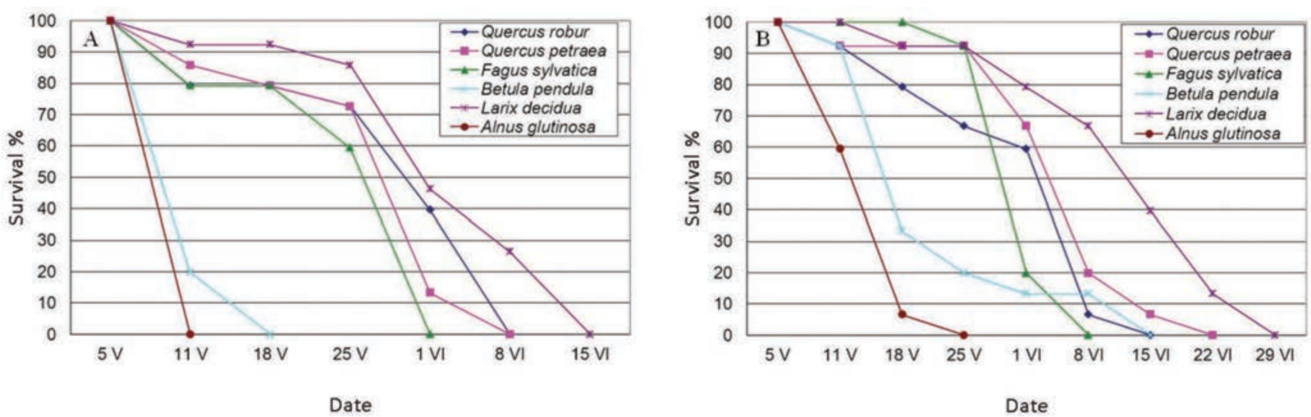


Figure 2. The survival of adult males (A) and females (B) of the may cockchafer feeding on the leaves of different tree species in the laboratory in 2011

gest life span was observed in males feeding on European larch foliage - 6 weeks. In the same way, common cockchafer females endured on European larch for the longest period of time (8 weeks), whereas on black alder – just for 3 weeks (Fig. 2B).

In general, females of both tested cockchafer species lived 2 weeks longer than males.

Body weight

In the period between 5 and 11 May 2011, there were found no statistically significant effects of diet on RGR of forest cockchafer males (Fig. 3A). The highest weight gain was observed in females feeding on sessile oak leaves. When compared to other tree species tested (with the exception of pedunculate oak), RGR of forest cockchafer females feeding on sessile oak was significantly higher (Fig. 3B). The lowest male and female RGR values (negative) were observed in specimens feeding on black alder, European larch and silver birch.

At the same time, the highest RGR values in common cockchafer males were obtained in those feeding on sessile oak and European larch leaves. Males feeding on beech and silver birch leaves achieved lower RGR values, and no male survived on black alder leaves longer than 7 days (Fig. 4A). The results obtained showed no statistically significant differences. Similarly to forest cockchafer females, RGR values obtained in common cockchafer females were the highest in specimens feeding on both oak species tested, and the lowest (significantly different when compared to both oak species) - on the leaves of black alder and silver birch (Fig. 4B). European larch needles and common beech leaves represented medium quality food for the insects tested.

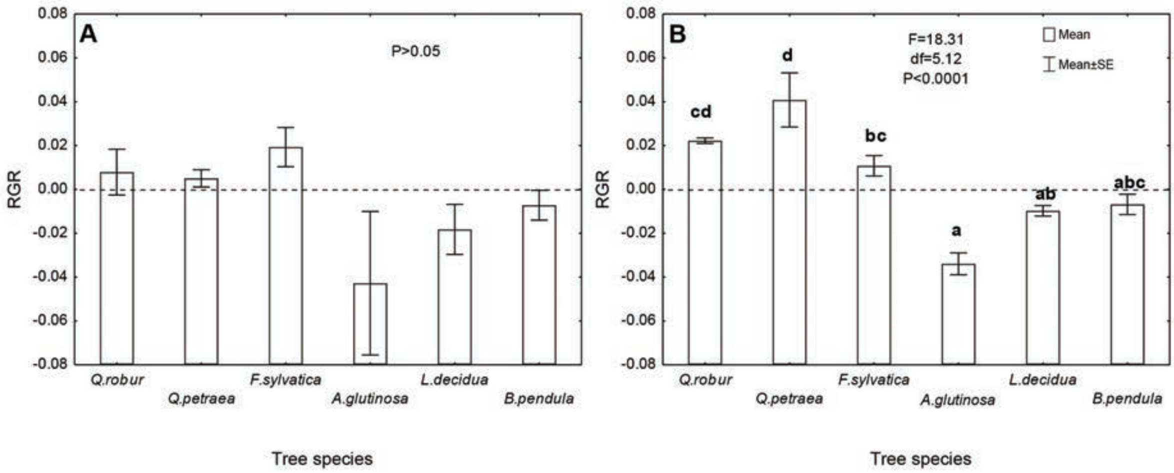


Figure 3. Relative weight gain of males (A) and females (B) of the forest cockchafer feeding on the leaves of various tree species in the laboratory in the period 5–11 May 2011

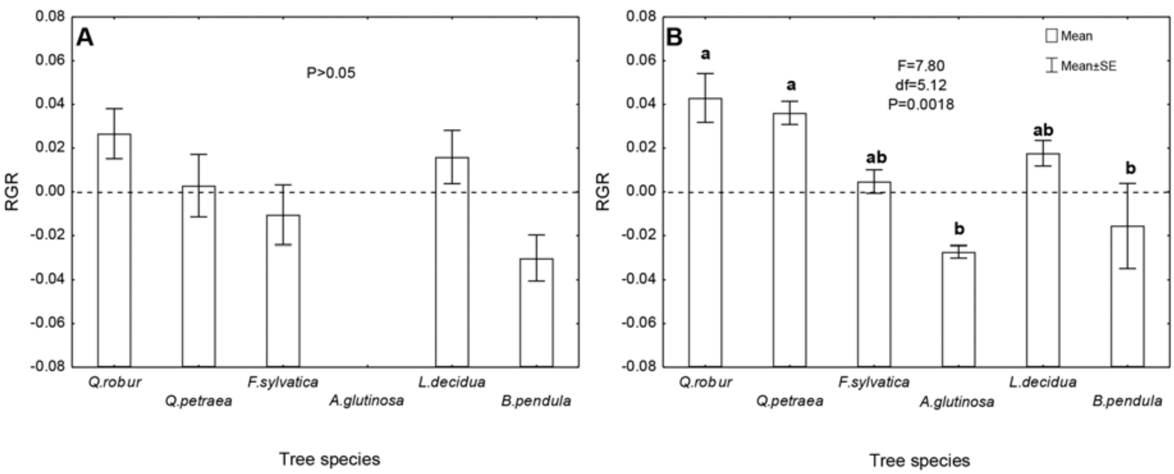


Figure 4. Relative weight gain of males (A) and females (B) of the may cockchafer feeding on the leaves of various tree species in the laboratory in the period 5–11 May 2011

Fecundity

The mortality and prompt decomposition of eggs deposited in sand observed during the tests on cockchafer female fecundity prevented drawing credible conclusions. Yet, healthy cockchafer eggs were found on host plant leaves (Fig. 5), at some stage of observations conducted on cockchafer life span (when no substrate for egg deposition was provided).

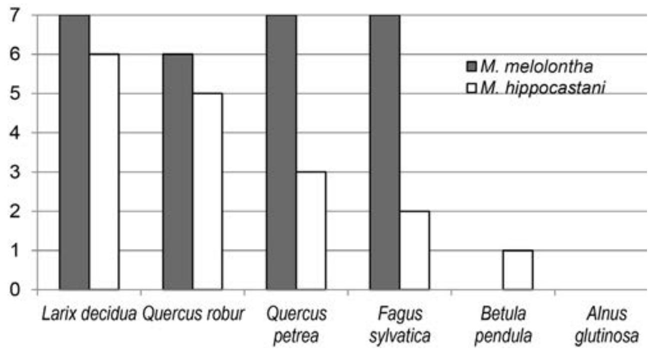
The number of cockchafer egg-masses found on the leaves of host plants tested, indicated a relationship between feeding on a given plant species and fecundity. Under the conditions of the present study, the majority of egg-masses were found on the walls of the glass containers with European larch and oak shoots (Fig. 6). In all the containers with birch shoots, there was found just one egg-mass and in those with black alder - none. When compared to forest cockchafer, more egg-masses were found in the containers with common cockchafer adults, who seemingly were less vulnerable to experimental conditions in the glasshouse, including increased temperatures during hot days. Common cockchafer females feeding on European larch foliage laid almost as many egg-masses as those on the shoots of common beech and both oak species. No egg-masses were found when females fed on silver birch and black alder leaves.

3.2. Effects of undergrowth tree species on cockchafer life span, weight gain and fecundity

Life span

The results obtained in 2013, showed the shortest life span (2 weeks) in forest cockchafer feeding on the leaves of black elder (females and males) and false acacia (males) (Fig. 7A, B). On the other hand, forest cockchafer females

Figure 5. May cockchafer eggs on the leaves of beech



Rycina 6. Number of egg masses laid by females of *M. melolontha* and *M. hippocastani* depending on trees species on which they were feeding on

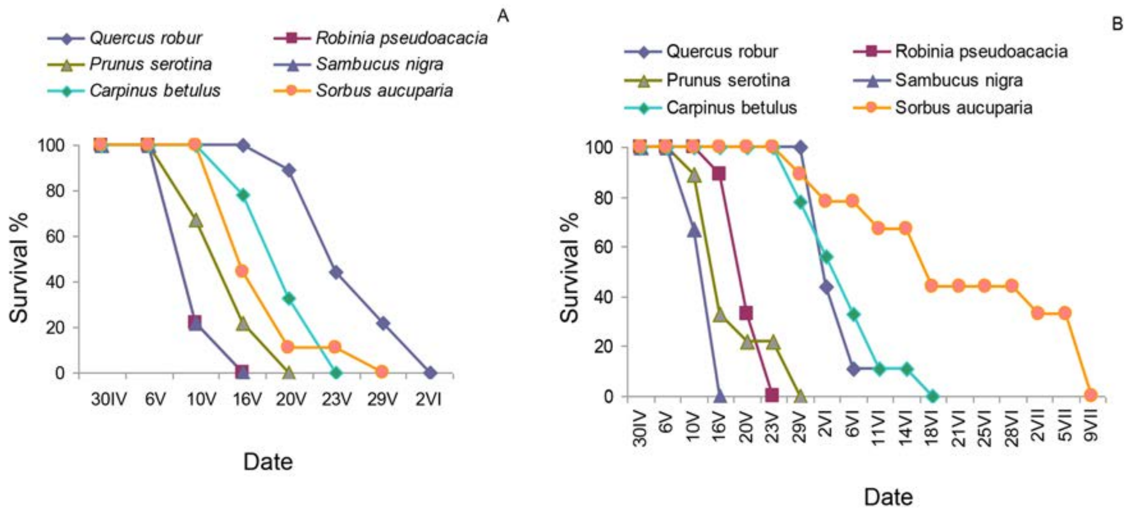


Figure 7. The survival of adult males (A) and females (B) of the forest cockchafer feeding on the leaves of different plant species in field conditions in 2013

feeding on rowan leaves lived longer than 70 days, i.e. about 3 weeks longer when compared to forest cockchafer specimens feeding on other host plant species tested. Forest cockchafer males lived the longest on the leaves of pedunculate oak (about 5 weeks). The average life span was 2 weeks longer in females when compared to that in males.

Likewise, life span of common cockchafer adults (females and males) was the shortest when they fed on the leaves of black elder (Fig. 8A and B). The longest life (8 weeks) was observed in common cockchafer females feeding on common hornbeam and rowan leaves. During the first 4 weeks of observations, female survival on oak leaves was 100%, but soon it rapidly decreased (Fig. 8B). In general, common cockchafer females and males lived longer on the leaves of pedunculate oak, rowan and common hornbeam when compared to other food plants tested. On the whole, common cockchafer females lived about 2 weeks longer when compared to males of this species.

Body weight

In the period of 30 April–6 May, the RGR values obtained were the highest in forest cockchafer males feeding on the leaves of pedunculate oak, common hornbeam and rowan. Negative RGR values were observed in forest cockchafer males feeding on the leaves of false acacia, black cherry and black elder (Fig. 9A). Nonetheless, these differences were not statistically significant.

Differentiation of RGR values was more evident in females when compared to males. The highest RGR values were obtained in females feeding on sessile oak leaves (Fig. 9B). Except for the leaves of common hornbeam, RGR value in females feeding on sessile oak was significantly higher when compared to other host plants tested. Negative RGR values were obtained in females feeding on black cherry and black elder leaves.

During the observation period of 13–20 May, the highest body weight gain in common cockchafer males was observed in those feeding on the leaves of common hornbeam and pedunculate oak (Fig. 9A). The biggest weight drop was recorded in males feeding on the leaves of black elder and black cherry. However, the differences observed were not statistically significant.

In common cockchafer females, positive RGR values were obtained for those feeding on the leaves of common hornbeam and pedunculate oak. Females feeding on the leaves of black elder, black cherry, false acacia and rowan showed negative RGR values, i.e. their body weight decreased in the period of 13–20 May. Body weight of females feeding on black elder, black elder and false acacia was significantly lower when compared to that of females feeding on pedunculate oak. (Fig. 10B).

Fecundity

During the whole observation period, forest cockchafer females laid 209 eggs all in all. The highest numbers of eggs were laid in the glass containers (9 of 10) with pedunculate oak shoots, on average 14.3 eggs/container. This indicates that of all the host plants tested (11 tree and undergrowth species), pedunculate oak was the most valuable food for forest cockchafer females. The mean numbers of eggs laid by females feeding on other host plants tested (rowan – 4.4, black cherry – 1.9, common hornbeam – 0.4) were significantly lower when compared to pedunculate oak. (Fig.11A). Forest cockchafer females feeding on black elder and false acacia laid no eggs.

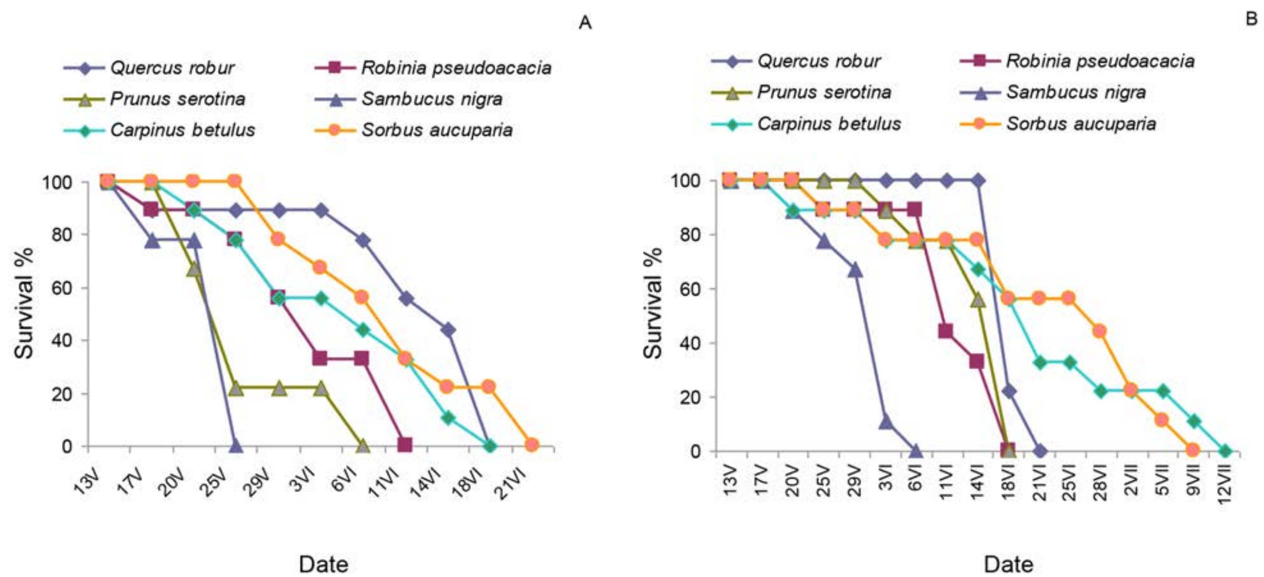


Figure 8. The survival of adult males (A) and females (B) of the may cockchafer feeding on the leaves of various plant species in field conditions in 2013

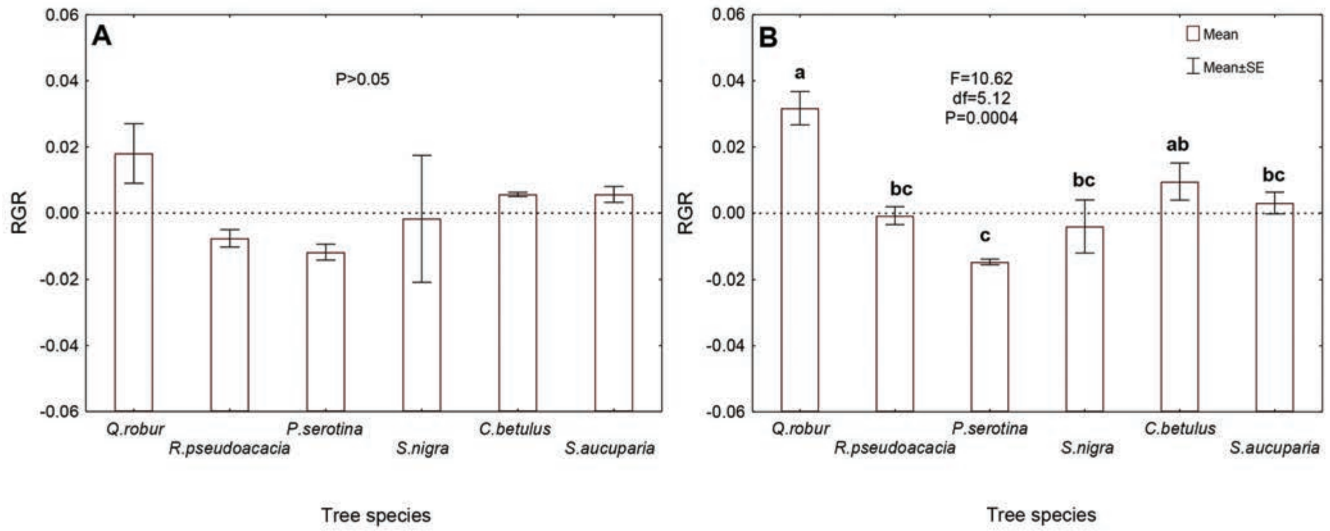


Figure 9. Relative weight gain of adult males (A) and females (B) of the forest cockchafer feeding on the leaves of various plant species in field conditions in the period from 30 April to 6 May 2013

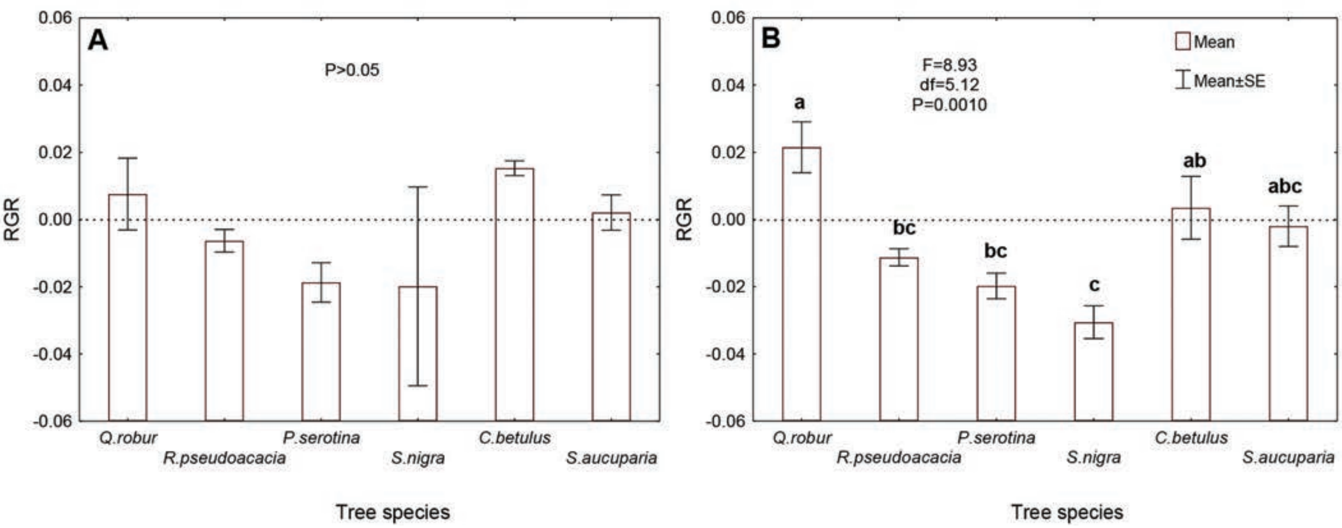
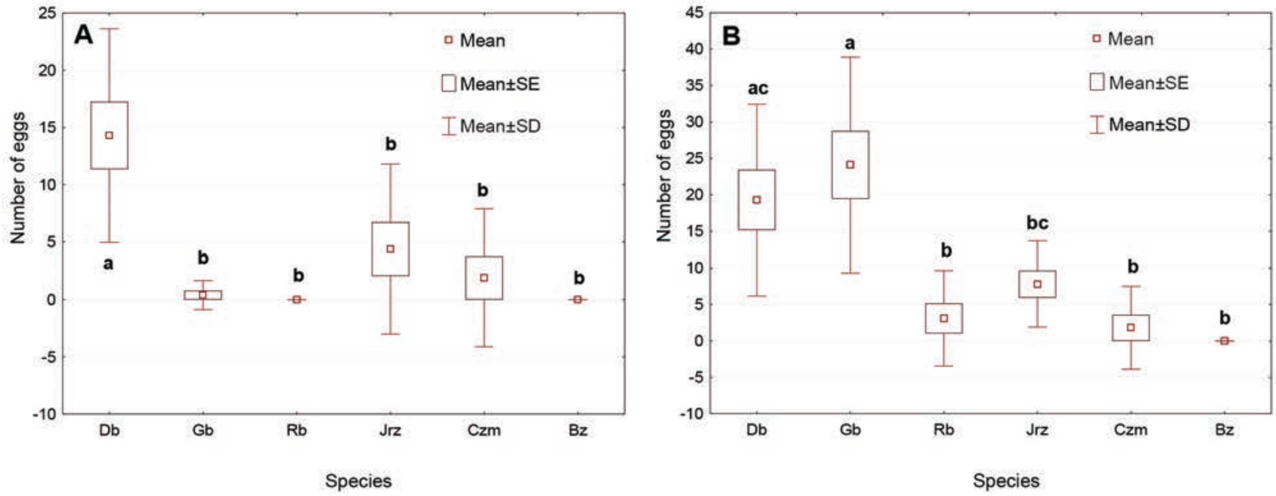


Figure 10. Relative weight gain of adult males (A) and females (B) of the may cockchafer feeding on the leaves of various plant species in field conditions during the period from 13 to 20 May 2013

Under the conditions of the present study, common cockchafer females laid altogether 561 eggs and 434 of these were laid by females feeding on the leaves of pedunculate oak (on average 19.3 eggs/container) and common hornbeam (24.1 eggs/container). No statistical differences between oak and hornbeam were found as regards egg numbers laid (Fig. 11B). Similarly, no statistical differences were found between oak and rowan (7.8 eggs/container). There were laid eggs in two containers with females feeding on false acacia (on average - 3.1) and in one container with black cherry (on average - 1.8). Common cockchafer females laid no eggs only when fed on black elder leaves. There were found no statistical differences among mean egg numbers laid in the containers with rowan, false acacia, black cherry and black elder, however, all these were significantly lower when compared to the mean number of eggs laid by common cockchafer females feeding on common hornbeam shoots.

4. Discussion

The assessment of cockchafer food preferences performed under the conditions of the present study comprised tree species that commonly occur in Poland's forests, inclu-



Rycina 11. The average number of eggs laid by females of (A)*M. hippocastani* and (B) *M. melolontha* depending on the species of plants, on which they were feeding on [Db – *Quercus robur*, Gb – *Carpinus betulus*, Rb – *Robinia pseudoacacia*, Jrz- *Sorbus aucuparia*, Czm – *Prunus serotina*, Bz – *Sambucus nigra*]

ding understory. The results obtained showed that the type of diet was an important factor affecting cockchafers adults' life processes. A number of the tree species tested provided the cockchafer species tested with valuable diet, whereas feeding on some - considerably decreased cockchafer vitality and fecundity, shortened life time or caused death due to starvation in extreme cases.

Insects can be discouraged or attracted to potential host plants, depending on plant chemical composition. The main factor responsible for the approval of plant taste by insects is the content of sugars (essential food components) in plant tissues (Harborne 1997). Next to sugars, most needed food components are proteins, free amino acids, vitamins, phospholipids and microelements. Apart from biologically active compounds with imperative physiological roles in plants, there also occur the so called specific substances. These are often secondary metabolites (Lewkowicz-Mosiej 2003), such as glycosides, alkaloids, saponins, flavonoids, bitter organic compounds, tannins, aromatic compounds, essential oils, terpenes, oils, organic acids, glucokinines, mucilage, phytohormones, mineral salts as well as vitamins (Sarwa 2001). As a general rule, relatively high concentrations of plant tannins (e.g. flavonoids) commonly occur in the leaves of woody plants and act as insect feeding deterrents (Harborne 1997). It is believed that glycosides and alcaloids have negative effects on insects, and are poisonous at high concentrations. Numerous secondary plant metabolites show strong toxicity against insects. In 1945, McIndoo enlisted 1180 plant species with a range of compounds toxic to insects, but the effects of the majority of them have not been up to date studied in depth. The toxins that have been already distinguished are for example: cyanogenic glycosides, glucosinolates, alkaloids, peptides, iridoids, furanocoumarins and saponins (Harborne 1997).

Literature data indicate that cockchafer adults readily feed on deciduous tree species such as oak, birch, rowan, beech, hornbeam and maple as well as on coniferous European larch (Sierpiński 1975). Only under unusual conditions (e.g. in the environment with no other tree species in the vicinity), cockchafers feed on the leaves of lime (*Tilia*), alder (*Alnus*), viburnum (*Viburnum*), ash (*Fraxinus*) and black elder (*Sambucus*). What is the difference between the leaves chosen as food and those rejected? The answer to the question considers chemical composition of a given plant, leaf concentrations of a variety of chemical substances with either positive or negative effects on insects, and also – so far not identified mechanisms.

Nunberg (1934) refers to oak and birch leaves as diet preferred by cockchafer adults. In the present study, the leaves of pedunculate oak and sessile oak constituted well-balanced diets for the tested cockchafer species, with beneficial effects on adult body weight gain in the first days after emergence and life span, as well as on the number of eggs laid by females. According to Kozłowski (2008), among all the host plant species tested thus far, oak is the one selected by the largest part of insect species (400 - in Poland, 1200 - all over the world). In our region, cockchafer adults emerge in the spring (April/May) and feed on young oak leaves – then with relatively low tannin concentration. At higher concentrations (increasing with leaf age), tannins act as insect repellents (Feeny1970). Young oak leaves are soft and consist of high amounts of amino acids along with peptides rather than highly toxic substances, hence, they are particularly attractive diet for cockchafer adults (Kozłowski 2008).

In the present study, beech leaves showed lesser quality as adult cockchafer food when compared to oak leaves. This could be due to not favorable for beech experimental conditions, e.g. occasionally too high daily temperatures in the glasshouse - fatal for fragile beech foliage. Consequently, value of beech diet could be decreased when compared to other plant species tested as cockchafer food. Furthermore, beech leaves contain flavonoids, organic acids and beech bark – tannins (Podgórski, Podgórska 2009). Flavonoids act as deterrents, and are known as the most important barrier against insect feeding on angiosperms (Harborne 1997). The aforesaid factors could be the reason of the observed lower quality of beech diet.

Leaf morphological features (e.g. size, thickness) and leaf surface shape (e.g. trichomes, fissures, prickles) as well as wax coverage are important factors in the process of host plant selection (Malinowski 2008). When compared to foliage of other coniferous trees, European larch needles are soft and delicate. It would seem that these very features had beneficial effects on cockchafer adults under the conditions of the present study – females feeding on European larch needles lived rather long and laid quite a number of eggs. In the present study, the leaves of common hornbeam - the tree species readily chosen by adult cockchafers as host plant (Sierpiński 1975) – represented appropriate diet, but only for common cockchafer adults. Forest cockchafer females feeding on common hornbeam showed comparatively low fecundity, which confirms earlier results obtained by Woreta and Sukovata (2010).

Adults of both cockchafer species tested in the present study consumed rowan leaves, however, the numbers of eggs laid by females were considerably lower when compared to females feeding on oak leaves. Rowan fruits contain: tannins, carotenoids, anthocyanins, vitamin C as well organic acids, including toxic parasorbic acid (Mazerant 1990; Serwa 2001). As a general rule, toxic compounds occur at different concentrations in all rowan tissues. Presumably, the presence of parasorbic acid in rowan leaves decreased their quality as cockchafer diet. Interestingly, silver birch leaves also showed low quality as diet for both cockchafer species observed. Forest cockchafer adults feeding on silver birch showed low body weight gain and fecundity, whereas common cockchafer adults did not accept silver birch leaves at all. These results confirm earlier conclusions by Woreta and Sukovata (2010).

Silver birch leaves contain: flavonoids, saponins, essential oils, malic acid, citric acid, tannins, anthocyanins as well as mucilage (Kosiński, Krzyściak-Kosińska 2008). Black alder leaves contain: tannins, triterpenes, hyperoside (3-O-galactoside of quercetin), resins and essential oils (Podgórski, Podgórska 2009). Some of these compounds are known as toxic to insects. In Poland, silver birch produces new leaves already in April, and these can be temporarily eaten by early emerging forest cockchafer adults, before they begin feeding on oak leaves or the leaves of more preferred tree species.

The results obtained showed unfavorable effects of black cherry and false acacia on cockchafer adults. Black cherry leaves, shoots, bark and seeds contain cyanogenic glicosydes. When the plant is injured (e.g. during insect feeding), the sugar part of the molecule is removed enzymatically and toxic hydrogen cyanide with bitter taste is released (Sarwa 2001; Olszewska 2007). Likewise, false acacia tissues are toxic, however, their concentrations in plant are considerably differentiated (Bohne, Dietze 2008). The group of active ingredients in false acacia flowers include organic acids, glycosides, essential oils as well as sugars (Sarwa 2001).

The results of the present study showed that cockchafer adults did not even try to consume black alder and black elder leaves, although no other food was available. As mentioned before, black alder leaves contain hyperoside (Podgórski, Podgórska 2009), i.e. flavonoid with possible deterrent properties against cockchafers. Furthermore, black alder leaves among others contain resin, i.e. a complex mixture of among others terpenes, resin acids, alcohols, esters, hydrocarbons and phenols (Podbielkowski 1992), and probably these compounds discourage adult cockchafers from consuming black alder leaves. Equally, black elder leaves have strong smell and contain toxic cyanogenic glycoside – sambunigrin (Sarwa 2001; Wilgosz 2008), which most probably is responsible for preventing cockchafer feeding on this plant species.

5. Conclusions

The present study was carried out with the aim to assess the effects of different host plant species on endurance, weight gain and fecundity of adult cockchafers. Food preferences of two cockchafer species (forest cockchafer *M. hippocastani* and common cockchafer *M. melolontha*) were tested with the use of tree species widespread in Poland's forests (both in the canopy and undergrowth). The results obtained showed that the leaves of pedunculate oak as well as those of sessile oak constituted the most beneficial diets for both cockchafer species tested, in terms of their survival, body weight gain and fecundity. At the same time, common hornbeam and European larch foliages represented suitable diet for common cockchafer adults, and not as much – for forest cockchafer adults. Then again, the leaves of common beech and rowan were better diets for forest cockchafer adults when compared to common cockchafer. Silver birch provided low quality diet for forest cockchafers and had negative effects on common cockchafers. The females of the latter species laid no eggs when fed on silver birch leaves. Black cherry and false acacia showed negative effects on cockchafer adults studied. Black alder and black elder represented the poorest diets (hardly ever consumed) for both cockchafer species studied.

The results obtained could be a basis for further research aiming at elaboration of environment friendly methods for successful control of abundant populations of forest insect pests.

Conflict of interest

No potential conflicts are declared by the authors.

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References

Bohne B., Dietze P. 2008. Rośliny trujące. 170 gatunków roślin ozdobnych i dziko rosnących. Warszawa, *Bellona* S.A., 128 s.

Brenner H., Keller S. 1996. Protection of orchards from white grubs (*Melolontha melolontha* L.) by placements of nets. Integrated control of soil pests. *IOBC/WPRS Bulletin* 19(2): 79–82.

Feeny P. 1970. *Ecology* 51: 565–581.

Harborne J.B. 1997. Ekologia biochemiczna. Warszawa, Wydawnictwo Naukowe PWN, 351 s.

Karpiński J.J. 1950. Zagadnienie walki z chrabąszczem za pomocą grzyba *Beauveria densa* Pic. *Annales Universitatis*. MCS Lublin – Polonia 2, 29–68.

Kosiński M., Krzyściak-Kosińska R. 2008. Atlas ziół. Bielsko Biała, Pascal sp. z o.o., 272 s.

Kozłowski. M.W. 2008. Wyspy obfitości. *Matecznik Białowieski* 1, 8–10.

Kronauer H. 2007. Zu viele Waldmaikäfer im Hardtwald bei Karlsruhe. *AFZ der Wald* 62(13): 692–694.

Kronauer H. 2010. Massenvermehrung im Hessischen Ried. Prozessschutz für Waldmaikäer in Hessen. *AFZ der Wald* 65(6): 36–37.

Lazarević J., Perić-Mataruga V., Stojković B., Tucić N. 2002. Adaptation of the gypsy moth to an unsuitable host plant. *Entomologia Experimentalis et Applicata* 102: 75–86.

Lewkowicz-Mosiej T. 2003. Leksykon roślin leczniczych. Warszawa, Świat Książki, 368 s.

Malinowski H 2008. Strategie obronne roślin drzewiastych przed szkodliwymi owadami. *Leśne Prace Badawcze* 69(2): 165–173.

Mazerant A. 1990. Mała księga ziół. Warszawa, *Wydawnictwo Związków Zawodowych,* 280 s.

McIndoo N.E. 1945. U.S. Dept. Agr. Bur. Entom. Plant Quareatine, ET 661, 286 s.

Nunberg M. 1934. Chrabąszcz i jego zwalczanie. *Instytut Badawczy Lasów Państwowych w Warszawie,* seria C, nr 5.

Olszewska. M. 2007. Quantitative hplc analysis of flavonoids and chlorogenic acid in the leaves and inflorescences of Prunus serotina Ehrh. *Acta Chromatographic* 19: 253–267.

Ott A., Delb H., Mattes J., Schröter H. 2006. Erfolgreiche Regulierung eines Nebenflugstammes des Waldmaikäfers. *AFZ der Wald* 61(6): 312–315.

Podbielkowski Z. 1992. Rośliny użytkowe. Warszawa, Wydawnictwa Szkolne i Pedagogiczne, 575 s.

Podgórski A., Podgórska B. 2009. Drzewa w pomniki zaklęte. Drzewa pomnikowe w Rudzie Śląskiej. Katowice, KOS, 123 s.

Rożyński F. 1926. W sprawie walki z chrząszczem majowym (*Melolontha vulgaris*). *Przegląd Leśniczy*: 32–38.

Sarwa A. 2001. Wielki leksykon roślin leczniczych. Warszawa, Książka i Wiedza, 444 s.

Sierpiński Z. 1975. Ważniejsze owady – szkodniki korzeni drzew i krzewów leśnych. Warszawa, *PWRiL*, 222 s.

Strasser H., Schinner F. 1996. Current status of *Melolontha melolontha* control by the fungus *Beauveria brongniartii* in Austria. *IOBC/WPRS Bulletin* 19(2): 69–73.

Szafer W., Kulczyński S., Pawłowski B. 1986. Rośliny polskie. Część 1. Warszawa, PWN, 464 s.

Švestka M. 2010. Changes in the abundance of *Melolontha hippocastani* Fabr. and *Melolontha melolontha* (L.) (Coleoptera: Scarabeidae) in the Czech Republik in the period 2003–2009. *Journal of Forest Science* 56: 417–428.

Wielgosz T. 2008. Wielka księga ziół polskich. Poznań. *Publicat* S.A., 344 s.

Woreta D. 1995. Niepokojący wzrost znaczenia chrabąszczowatych w tym guniaka czerwczyka. *Głos Lasu* 8: 13–15.

Woreta D. 1997. Możliwości ograniczania szkód powodowanych przez pędraki chrabąszczowatych (*Melolonthinae*) metodami niechemicznymi. Sylwan 5: 29–39.

Woreta D. 2015a. Chrabąszcze *Melolontha,* w: Krótkoterminowa prognoza występowania ważniejszych szkodników i chorób infekcyjnych drzew leśnych w Polsce w 2015 r. Instytut Badawczy Leśnictwa, Analizy i Raporty 24, 82–83.

Woreta D. 2015b. Control of cockchafer *Melolontha* spp. grubs – a review of methods. *Folia Forestalia Polonica* 57(1): 33–41. DOI: 10.1515/ffp-2015-0005.

Woreta D., Sukovata L. 2010. Wpływ pokarmu na rozwój chrabąszcza kasztanowca (Melolontha hippocastani F.) (Coleoptera, Melolonthidae). *Leśne Prace Badawcze* 71(2): 195–199. DOI: 10.2478/v10111-010-0015-0.

Zelger R.1996. The population dynamics of the cockchafer in South Tyrol since 1980 and the measures applid for control. *IOBC/WPRS Bulletin* 19(2): 109–113.

Author's contribution

D.W. – conducting tests, study development, preparation of the manuscript, text revision; S.L. – conducting tests, study development, text revision; R.W. – conducting tests, text revision.

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