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The effect of environmental conditions on the abundance of grubs of the cockchafer (*Melolontha hippocastani* F.)

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ABSTRACT: In selected sample plots which included pine forest plantations, pine young growth, small pole stage of pine, pine high forest, mixed pine/oak stand, beech stand and unforested land the bionomics and the abundance of grubs were studied between two swarmings of *M. hippocastani* F. cockchafers in the period from 2003 to 2007. On the basis of correlations between the abundance of grubs and course of daily temperatures during swarming, and characteristics of the sample plots, particularly the degree of shading, we evaluated the factors which affected the *M. hippocastani* F. females in their choice of the locality for laying eggs. The correlation between the abundance of grubs and the shading of the locality was evaluated statistically. On the basis of checks of the soil probes the development of grubs and changes in their numbers were monitored in the period from 2004 to 2006.

Keywords: forest protection; *Melolontha hippocastani* F.; bionomics and abundance of grubs; environmental conditions

In the areas of mass outbreak the grubs of *Melolontha hippocastani* F. feed on the roots and cause considerable losses of forest tree species, namely pine, oak, linden and others. Grubs developing in one- and two-year plantings have the greatest impact on forest regeneration. The most endangered cultures are cultures established two years after the main swarming, i.e. at the time when the freshly planted plants are exposed to the feeding of grubs of the 2nd and 3rd instar in the two following vegetation periods. In terms of forest protection we must explore the climatic, ecological and economic factors to be able to explain what affects the egg-laying of females and the following feeding of grubs in high-risk localities, i.e. particularly in 1- to 5-years old forest plantations.

The objective of the study and the studied region

The objective of the study was to explore the life history (development and movement of grubs in the soil, width of the head of grubs) and to survey the abundance of grubs in the period between two swarmings of *M. hippocastani* F. in the years 2003 to 2007 in selected sample plots including pine forest plantations, pine young growth, small pole stage of pine, pine high forest, mixed pine/oak stand, beech stand and unforested land (Table 1). On the basis of correlations between the abundance of grubs and characteristics of the sample plots, particularly the degree of shading, to evaluate what factors affected the *M. hippocastani* F. females in their choice of the locality for laying eggs in 2003. The findings will be specified on the basis of similar investigations to be carried out in the following development cycle of *M. hippocastani* between 2007 and 2011.

Investigations were conducted in the Vracov locality (coordinates 48°58'6"N, 17°13'14"E) in the Strážnice forest district, altitude 193 m. In the Strážnice forest district the grubs destroyed 62.7 ha of young forest stands during the development cycle

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Table 1. Survey of sample plots

Type of stand	Age	Height (m)	Stand density	Site class
1 Pine high forest without undergrowth	97	25	6	4
2 Pine high forest with oak in undergrowth	89	23	9	4
3 Small pole stage of pine	31	12	10	3
4 Pine young growth	14	5	9	3
5 Beech stand	55	19	10	3
6 Area with no cover				
7 Young pine plantation	2.4			3

of *M. hippocastani* F. in 1999–2002, and in the following development cycle in 2003–2006, i.e. during our investigations, 86.5 ha of young forest stands.

The Vracov locality lies in south-eastern Moravia with long-term average air temperatures of 9.3°C and annual sums of precipitation around 450 mm. It is one of the warmest regions in the Czech Republic. A strong tribe of *M. hippocastani* F. with four-year development has been localized in the Vracov locality. One strong tribe of cockchafers inhabits the locality. The last two heavy swarmings took place in 2003 (Švestka 2006) and 2007. In the years between the two swarming years the adults appeared sporadically only in 2004 and 2006. In fact only one growth stage of grubs inhabits the soil and very rarely grubs of other growth stages.

MATERIAL AND METHODS

In the period from 2003 to 2007 swarming was monitored using light traps with an HQL 125 W discharge lamp. The number of trapped cockchafers and the sex ratio were recorded on the individual days in April and May 2003 and 2007 (Figs. 1 and 2).

The daily maximum, minimum and average temperatures during the vegetation period in 2003 to 2007 were recorded and evaluated by means of the automatic meteorological station 431 B (Fig. 3).

Research was conducted from April 2003 to May 2007. Field investigations were focused namely on monitoring the development and abundance of grubs in 50 × 50 × 50–60 cm soil probes. Soil was checked in various types of forest stands; pine forest plantations of 1 to 5 years of age; pine stand of 14, 31 and 97 years of age; 89-years-old mixed pine/oak stands; 55-years-old beech stand; and unforested area. Basic check in the particular years was conducted in April–May; in 2004, 2005 and 2006 the abundance and the development stage of grubs were checked on a total area of 22 m^2, 39 m^2 and 66 m^2, respectively. Apart from that random checks of the development of grubs were conducted on a monthly basis on an area of 1 m^2. The width of the head of grubs obtained from the soil probes was measured under a binocular. In total we measured 129, 174 and 338 1st instar, 2nd instar and 3rd instar grubs, respectively.

The difference between the abundance of grubs and degree of shading was assessed statistically using the analysis of variance (ANOVA). Repeated measurements with ANOVA were used for evaluat-

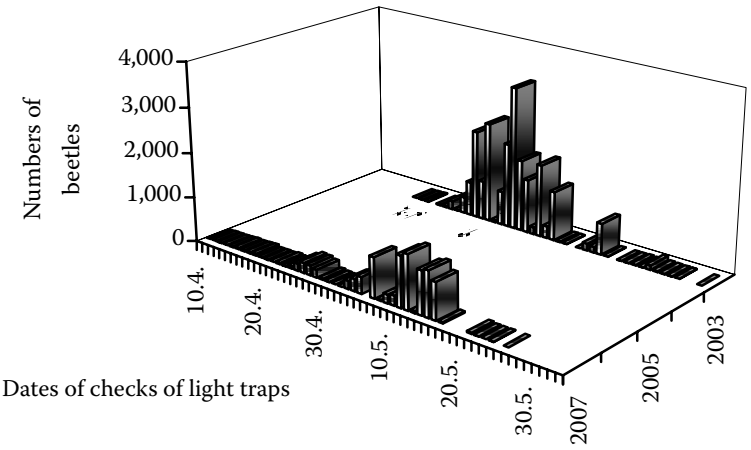

Fig. 1. The course of *Melolontha hippocastani* swarming, Vracov 2003, 2004, 2005, 2006, 2007

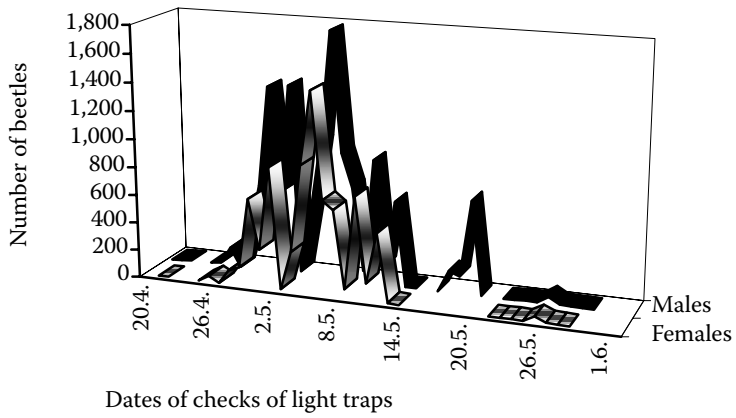

Fig. 2. The swarming of males and females of *Melolontha hippocastani* F., Vracov 2003

ing the differences between the respective degrees of shading taking into account the development in time (2003–2007). As the values for the individual levels of factors were considerably imbalanced and the normality and homoscedasticity of the individual groups was not proved (Shapiro-Wilks normality test and Bartlett's test of homoscedasticity were used), we also applied the non-parametric Kruskal-Wallis and Friedman's tests and successive test of multiple comparisons using the Statistica 8 programme (StatSoft, Inc. 2007).

RESULTS AND DISCUSSION

In 2003 *M. hippocastani* F. cockchafers in the Vracov locality swarmed in the period from 16 April to

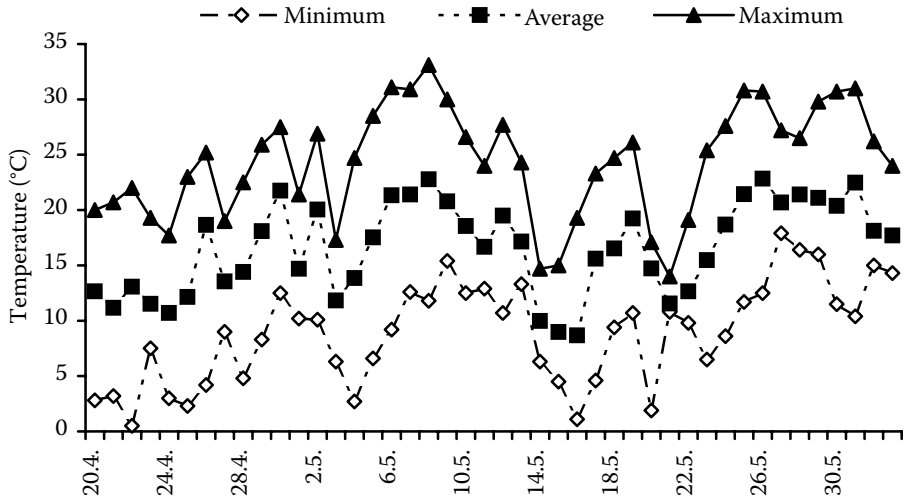

Fig. 3. Daily temperatures at the time of *Melolontha hippocastani* F. swarming in the Vracov locality in 2003

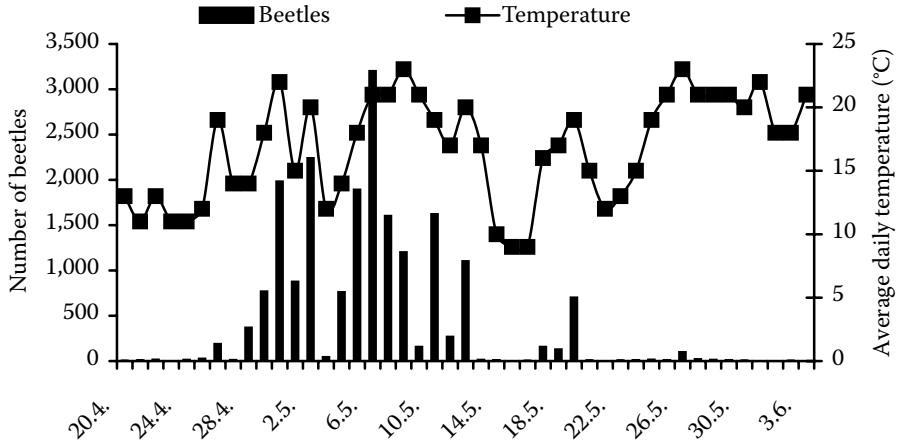

Fig. 4. Correlations between the average daily temperature and swarming of *Melolontha hippocastani* F., Vracov 2003

Table 2. Survey of the incidence of grubs of the 1st to 3rd instar and adults in 2004 to 2006

	Average number of grubs and adults/m^2			
	1st instar	2nd instar	3rd instar	adults
2004 – April	38.3	0	0	0.01
2005 – April	0	9.4	0.03	0
2006 – April	0	0.04	6.3	0.07

2 June. The maximum numbers of insects swarmed in the period between 28 April and 12 May. The average temperature in May 2003 was 17.37°C and during 15 days of peak swarming, between 28 April and 12 May, the average temperature was 18.22°C; during 4 days of this period the maximum temperature increased above 30°C (see Fig. 4). When we compared the temperatures in May 2003 with the 10-year average May temperature in the Vracov locality it was evident that in May 2003 the average temperature on the sample plot was by 2.3°C higher than the 10-year average. Within 5 days from 6 to 10 May 2003, i.e. in the period of the absolute peak of swarming when egg-laying was most frequent, the weather was tropical, the average temperature was 21°C, i.e. 6.6°C above the 10-year average (Švestka 2007).

The results of soil checks showed that the 1st instar grubs hatched from the eggs during June and July 2003 and then wintered at an average depth of 35 to 40 cm. In May 2004 the grubs appeared mainly at a depth of 10–20 cm, i.e. 97.8% of the 1st instar grubs and 2.2% of the 2nd instar. In July 2004 grubs of the 2nd instar prevailed, i.e. 86.7%, and of the 1st instar 13.3%. The grubs wintered at an average depth of 35–40 cm. In May 2005 the grubs were found predominantly at a depth of 10–20 cm; 99.2% were 2nd instar grubs and 0.8% 3rd instar grubs. During June and July 2005 the grubs moulted and passed into the 3rd instar stage. At the turn of June and July 2005 the percentage of the 2nd and 3rd instars was 16.5% and 83.5%, respectively. The grubs wintered at an average depth of 40–50 cm. In May 2006 the percentage of grubs of the 3rd and 2nd instars was 99.0% and 1.0%, respectively. In the second half of June and in July 2006 the grubs pupated. During late summer and in autumn 2006 the cockchafers which had wintered in the soil emerged. Table 2 gives a survey of the proportions of grubs of the 1st to 3rd instars and adults in 2004 and 2005 in the Vracov locality.

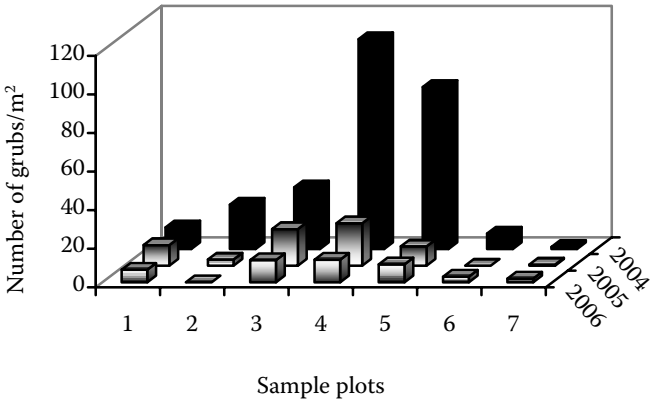

Fig. 5. The number of grubs in the period 2004–2006

Table 3. Abundance of grubs in various localities in 2004 to 2006

Type of stand	Number of grubs/m^2		
	2004	2005	2006
1 Pine high forest without undergrowth	11.2	10.7	6.5
2 Pine high forest with oak in undergrowth	23.0	3.2	0
3 Small pole stage of pine	32.0	19.0	11.5
4 Pine young growth	108.8	22.0	11.7
5 Beech stand	84.0	10.0	9.3
6 Area with no cover	8.0	0	2.9
7 Young pine plantation	1.1	0.6	1.9
Average number from all localities	38.3	9.4	6.3

Table 4. Abundance of grubs according to the degree of shading in 2004 to 2006

Sample plots	Number of grubs/m^2		
	2004	2005	2006
Heavily shaded (3, 4, 5)	75	17	12
Medium shaded (1, 2)	17	7	3
Not shaded (6, 7)	5	0	2

Measurements and evaluation of the temperatures at the time of egg laying in 2003 showed that they were markedly above the average (+ 6.6°C above the average). The results of evaluations of the abundance of grubs in localities of different degrees of shading of the soil surface in 2004 to 2006 correspond with these findings. The soil surface of localities 3, 4 and 5 is heavily shaded, the degree of shading of localities 1 and 2 is medium and localities 6 and 7 are not shaded at all.

Table 5. Average abundance of grubs in April and May 2005 and 2006

Medium number of grubs/m^2			
IV. 2005	V. 2005	IV. 2006	V. 2006
3.6	9.4	2.8	6.3

In 2004 the incidence of 1st instar grubs per 1 m^2 was the highest in pine young growth (108.8) and gradually decreased in the beech stand (84), small pole stage of pine (32), pine high forest with oak undergrowth (23), high forest pine stem-wood with no undergrowth (11.2), on unforested plots (8) and pine plantations (1.1). Based on results of the years 2005 and 2006 we discovered that in the period of the 2nd and 3rd instars the differences in the numbers of grubs in the respective localities remained but they gradually decreased (see Table 3 and Fig. 5) probably because the grubs gradually spread over the area and due to the impact of natural enemies.

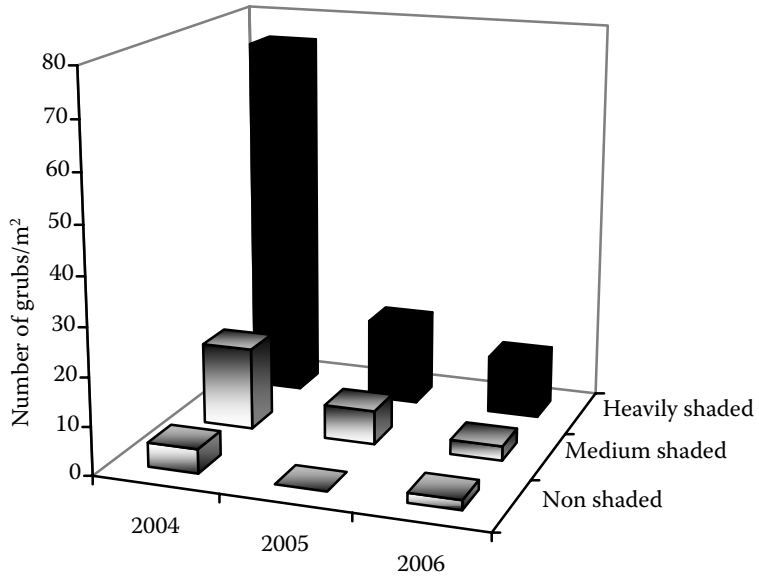

Fig. 6. The number of grubs based on the degree of shading

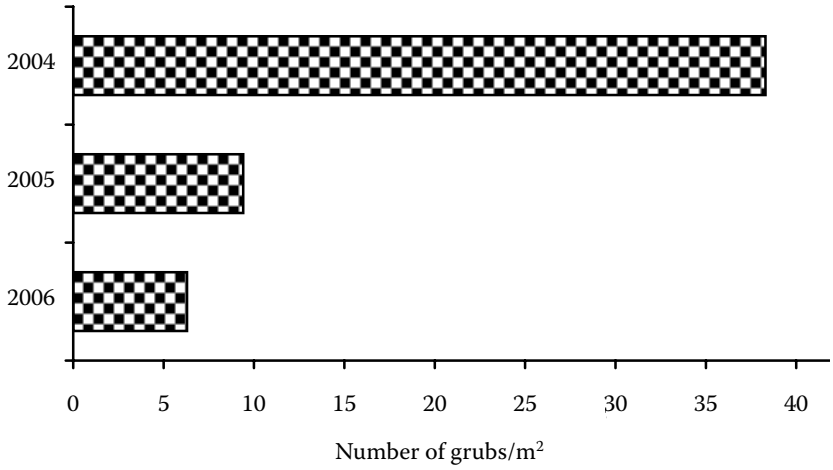

Fig. 7. Reductions in numbers of grubs in 2004–2006

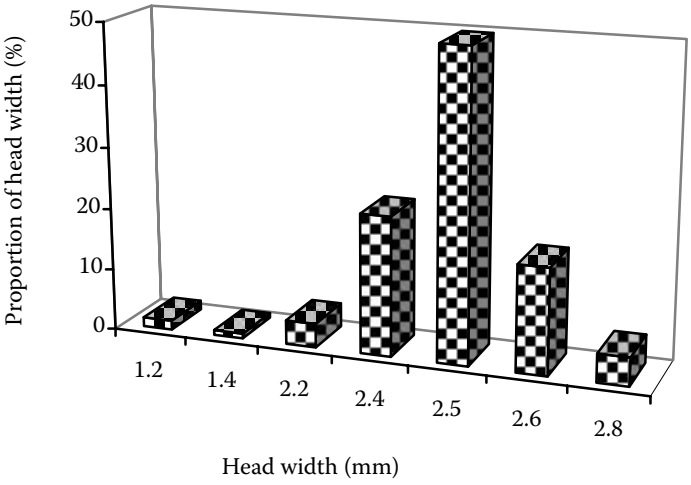

Fig. 8. The head width of 1st instar grubs

The highest initial number of 1st instar grubs in 2004 was discovered on heavily shaded areas; on average 75 grubs/m^2; on medium shaded areas on average 17 grubs/m^2 and on not shaded areas on average 5 grubs/m^2 (see Table 4 and Fig. 6).

Overall evaluations of the reduction in grub numbers on all localities in the Vracov region in the period from 2004 to 2006, i.e. in period of the 1st to 3rd instar of grubs, showed that the numbers of grubs considerably declined to 16% due to natural opponents and unfavourable natural effects, i.e. to one fifth to one sixth of the initial number (see Fig. 7).

The results of statistical evaluations are as follows:

In terms of the degree of shading we only very "narrowly" proved a statistically significant difference in the number of individuals (p = 0.04) at a significance level of α = 0.05; the greatest difference (on the "margin" of a significant difference) was observed between the heavily shaded localities and those that were not shaded at all. In localities where shading was only medium the abundance of grubs did not differ significantly from the other localities. The high variability in the number of grubs recorded in 2004 and the generally small selection greatly affected the statistical analysis of the abundance based on the particular years using ANOVA with repeated measurements; the result is considerably wide intervals of reliability. This is the reason why no statistically significant difference between the particular years (p = 0.16) was found at the α = 0.05 level of significance; however, because the requirements for the non-parametric ANOVA were not met, this method is not very significant. The non-parametric Friedman's test showed that the number of individuals discovered in 2004 differed from the other years (p = 0.01). Generally we can say that the numbers were the highest in 2004 (but including the high variability of the data); in 2005 and 2006 the counts were much lower, but did not differ very much.

Figs. 8, 9 and 10 show the results of measurements of the width of the head of the grubs. The head width

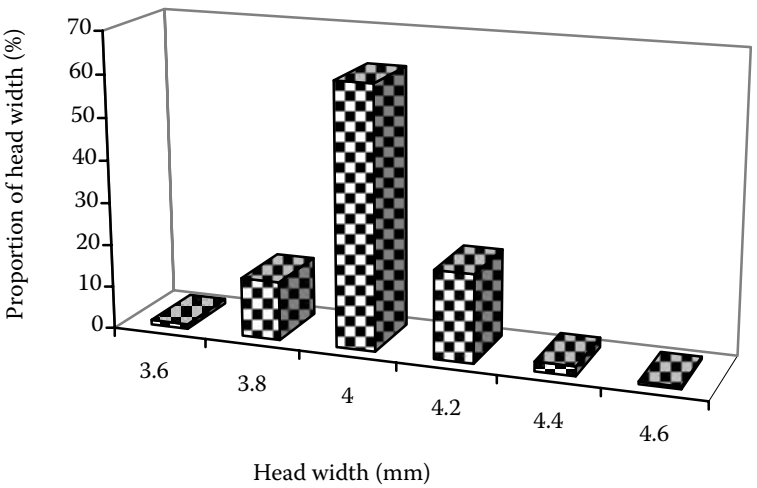

Fig. 9. The head width of 2nd instar grubs

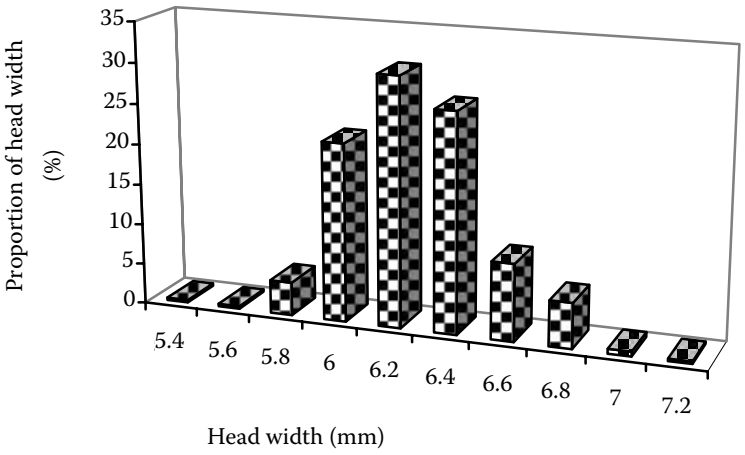

Fig. 10. The head width of 3rd instar grubs

of 1st instar grubs ranged between 1.2 and 2.8 mm, most frequently between 2.4 and 2.6 mm, of the 2nd instar grubs the head width ranged between 3.6 and 4.6 mm, most frequently 3.8 to 4.2, and the width of the heads of 3rd instar grubs ranged between 5.4 and 7.2 mm, most frequently 6.0 to 6.4 mm.

The differences in the numbers of grubs found in soil probes in April and May 2005 and 2006 indicated that the grubs climbed up into the top soil layers gradually in dependence on the increasing temperature. The numbers of grubs detected in April reached 38–44% of the final numbers found in May (see Table 5 and Fig. 11).

Information on the bionomics of *M. hippocastani* F. grubs collected in 2003 to 2006 corresponds with information of Hůrka (1955), who explored the bionomics and behaviour of grubs in the surroundings of Stará Boleslav in 1951 to 1954. The author pointed out that the vertical movement of grubs in the soil was affected to the greatest extent by the temperature (air temperature and subsequently the soil temperature). In spring the grubs move up when the temperature of the wintering soil rises to 7–10°C and in autumn they descend when the temperature of the inhabited soil layer cools down to 10–11°C. The grubs stay in the top layers of soil (ca 20 cm) on average five months (May to September) and in the year of swarming only two months.

CONCLUSION

In 2003 the *M. hippocastani* F. females laid the eggs during a period of markedly above-average temperature. It is necessary to take into account this fact when evaluating the correlation between the extent of plant losses in the 2004–2006 period and the individual ecological characteristics (Švestka 2007), and when evaluating the correlations between the incidence of grubs in the 2004–2006 period and characteristics of the sample plots, in particular the degree of shading. It will be useful to compare these findings with data obtained in the next developmental stage of *M. hippocastani* F., i.e. after 2007 (2008–2010) because in 2007 the eggs were laid under different meteorological conditions. The relation between the rate of shading of the locality and the abundance of grubs will be specified.

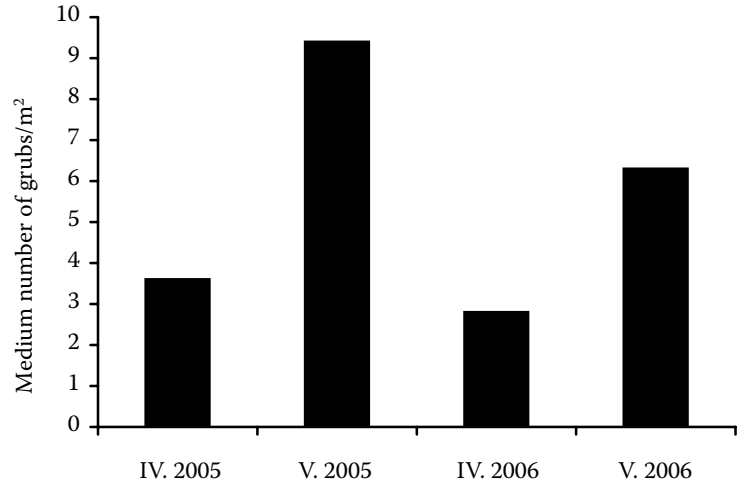

Fig. 11. The average incidence of grubs in April and May 2005 and 2006

Results of the checks of the numbers and development of grubs confirmed the preference of *M. hippocastani* F. females for localities heavily shaded by the forest stand. The difference in the numbers of grubs between heavily shaded and non-shaded areas was statistically significant. In their choice of the locality the *M. hippocastani* females likely prefer certain temperatures (humidity).

Due to the course of temperatures during the egg-laying period the females preferentially searched for shaded places, i.e. beneath forest stands, from the stage of young growth to high forest, while they avoided the open spaces of young forest plantations, particularly if the weed cover was also reduced (Švestka 2007). This fact is useful in terms of forest protection because saplings can outlive grub feeding on the roots. In spite of these circumstances, due to the mass outbreak and dense population of *M. hippocastani* F., the forest plantations in the monitored area were seriously damaged in the period of 2004–2006.

The previous findings of Flerov et al. (1954) and Záruba (1956) were confirmed once again, i.e. that the choice of the locality for laying eggs is influenced by the actual temperature. When the temperatures were high, the females chose areas shaded by the crowns or by weeds and at cold temperatures they gave preference to more open localities.

It is logical that the initial number of grubs in the period of the 1st instar was the highest and that during the 2nd and 3rd instar stages the numbers of grubs gradually decreased to 16% of the initial count.

The head widths of *M. hippocastani* F. grubs were 1.2–2.8 mm, 3.6–4.6 mm and 5.4–7.2 mm in the 1st, 2nd and 3rd instar, respectively. These values are smaller than the generally given dimensions for *M. melolontha* L.: 2.1–3.1 mm for the 1st instar, 3.7–5.0 for the 2nd instar and 5.7–7.6 for the 3rd instar (Kapitola, Holuša 2002).

Study of the bionomics of *M. hippocastani* F. grubs enabled to describe the development of the grubs from hatching to pupation and especially to determine the period when they would pose a threat to forest plantations. The harmful feeding of grubs of the 2nd and 3rd instars is concentrated into 4 months (June–September) in the second year after swarming; into five months (May–September) in the third year after swarming; and into two months (May–June) in the fourth year after swarming. In these periods the forest plantations are endangered in places of mass outbreak. At the present time this danger arose in the Vracov region in June 2008 and it will last until July 2010.

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Vliv podmínek prostředí na početnost ponrav chrousta maďalového (*Melolontha hippocastani* F.)

ABSTRAKT: Ve vybraném souboru zkusných ploch, zahrnujících borové lesní kultury, borovou mlazinu, borovou tyčkovinu, borovou kmenovinu, smíšený porost borovice a dubu, bukový porost a nezalesněnou plochu, byla studována bionomie a hodnocena početnost ponrav *M. hippocastani* F. v období mezi dvěma rojeními v letech 2003 a 2007. Na základě posuzování vztahu mezi početností ponrav a průběhem denních teplot v době rojení i charakteristikami pokusných ploch – zejména mírou zastínění – bylo hodnoceno, jaké okolnosti ovlivnily samice *M. hippocastani* F. při výběru lokality pro kladení vajíček. Vztah mezi početností ponrav a mírou zastínění lokality byl statisticky

vyhodnocen. Na základě půdních kontrol byl zhodnocen průběh vývoje ponrav v období let 2004 až 2006 i změny jejich početnosti v průběhu daného období.

Klíčová slova: ochrana lesa; *Melolontha hippocastani* F.; bionomie a početnost ponrav; podmínky prostředí

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