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Influence of moisture, diameter and bark thickness of traps on the emergence behaviour of *Chaetoptelius vestitus* (Insecta, Coleoptera, Scolytidae)

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This paper concerns the influence of inside moisture, diameter and bark thickness of traps (cut branches from the tree *Pistacia vera* L.) on the emergence and dispersal flight of the new adult bark insects of *Chaetoptelius vestitus*. Data showed that there is a difference in the time of emergence and flight of the new adults among traps of different inside moisture, diameter and bark thickness.

Key words: Bark beetles, *Chaetoptelius vestitus*, branch traps.

INTRODUCTION

Chaetoptelius vestitus Muls. and Rey, Fuchs is a bark boring, engraver beetle (Coleoptera: Scolytidae) (Jaques, 1951; Balachowsky, 1963; Berryman, 1968). It is a serious agricultural pest, which attacks mainly twigs and branches of the *Pistacia* species. The *C. vestitus* larvae are feeding in the bark and subbark zone of the host branches (Russo, 1925a,b; 1926). After completing their development, the newly emerged adults perforate the barks and open exit tunnels.

Studies on other genera of Scolytidae showed that insect development is affected by environmental conditions (Blackman, 1919; Smith, 1932; 1945; Wood, 1963; Cole & Shepherd, 1967; Stark & Dahlsten, 1970; Bright & Stark, 1973; Bright, 1976). However, there are no relevant studies referring to *C. vestitus*.

In the present work, the influence of the inside moisture, diameter and bark thickness of host branch traps on the emergence and flight behaviour of new adults of *C. vestitus* was studied.

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MATERIALS AND METHODS

Experiment I

To investigate the influence of inside moisture on the emergence and flight behaviour of *C. vestitus* new adult insects, one hundred traps were used, which were exposed to the orchard. Traps were fresh cut from not attacked branches of *Pistacia vera* L. trees. These branches (of almost the same diameter and bark thickness), which were paraffined at their cut ends to preserve the inside moisture, were used for reproduction of the attracted adults of *C. vestitus*. In all traps, the reproductive galleries were excavated by the adults during the same period. They were hanged separately, with their cut end to the soil in a distance of 15-25 cm from each other, until the emergence of the new generation.

After the emergence of the first new adults from each trap, the inside moisture of this trap was measured. The moisture of the traps was estimated as the amount of water in relation to the dry weight of the trap. Because of the presence of volatile ingredients in the branchtraps (Fragoulis, unpublished data), dry weights were determined by keeping the traps in vacuum, at 60˚C temperature for 8 hours. The final results were expressed as a percentage of the differences of the weights of the traps before and after desiccation in the vacuum.

The emergence time of the individuals from the traps was recorded with a chronometer, taking into account that the emergence time of the first new generation insects was 1 min. The emergence of new adults was ascertained by observing the exit holes in the branchtrap.

Experiment II

To investigate the influence of the diameter and bark thickness of the traps on the emergence and flight behaviour of the new adult insects of *C. vestitus*, forty branchtraps (of almost the same inside moisture) were simultaneously exposed to the orchard. The diameter and the bark thickness of eash branchtrap were measured with a caliper (micrometer, pachymeter), before and after the barking, and the results were expressed in cm (trap diameter) and in mm (bark thickness). The emergence time of the individuals from the traps was recorded as in experiment I. As time of emergence of new adults from each trap was considered the time delay from the trap, where emergence of new adult insects was first observed in each experiment.

Statistical analysis

Data of the experiment I were not normally distributed, therefore we used non-parametric statistics, Kruskall-Wallis H-test and Tukey W-test, to assess the differences. Since data in experiment II were normally distributed, variance f-test and T-test were used to check emergence mean time differences (Sokal & Rohlf, 1969).

RESULTS

Experiment I. Moisture of traps and emergence time of the new adult insects of C. vestitus

Some of the used branchtraps were destroyed and the remaining (84) were grouped into seven categories (40%, 35%, 33%, 28%, 25%, 18% and 16%), of twelve traps each, according to the inside moisture.

Table 1 shows the differences in the emergence and flight time of the new adults of *C. vestitus* among traps of different inside moisture. The highest moisture found in the traps was 40% (39.486% ± 0.598), while the lowest one was 16% (16.236% ± 0.238). To determine the emergence time of the new adults we considered (scored) as 1 min the time that the first new adults exited from the trap with the highest moisture (40.225%). Thus, for the group of traps

TABLE 1. Inside moisture of traps and corresponding emergence time of the new adult insects of *Chaetoptelius vestitus*. (N=12, number of traps in each group)

Mean values (%) Moisture ± S.D.	(%) Moisture Min. - Max.	Mean values Emerg. time ± S.D. in min	Emergence time Min. - Max. in min	Range time in min	Statistical analysis
16.236 % ± 0.238	15.97 - 16.55	1577.333 ± 19.19	1553 - 1603	50	1. H - test
18.051 % ± 0.081	17.958 - 18.21	1349.5 ± 8.512	1338 - 1365	27	H = 81.331 with df = 6
25.102 % ± 0.14	24.89 - 25.365	643.833 ± 6.913	633 - 655	22	and P<0.001
28.068 % ± 0.16	27.855- 28.355	479.25 ± 9.372	463 - 493	30	
33.045 % ± 0.106	32.89 - 33.21	72.917 ± 5.017	65 - 81	16	2. W - test
35.049 % ± 0.08	34.93 - 35.212	20.833 ± 4.019	15 - 27	12	W = 13.8418
39.486 % ± 0.598	38.62 - 40.225	2.583 ± 1.443	1 - 5	4	

with 40% inside moisture, the minimum emergence time was 1 min, for the traps with 35% it was 15 min, for those with 33% 65 min, with 28% 463 min, with 25% 633 min, with 18% 1338 min, and with 16% 1553 min. Data showed that there was a delay of about 1575 min in the mean (emergence time) value, between the traps of 16% and 40% inside moisture (1577.333 min - 2.583 min = 1574.750 min) (Table 1).

From the differences between the minimum emergence time of the low moisture traps and the maximum emergence time of the high moisture traps (Table 1) it was found that:

i) The new adult insects from the traps with 35% moisture emerged 10 min after the completion of emergence from the traps with 40% moisture.

ii) There was a 38 min delay in the emergence of the new adults from the traps with 33% moisture compared to the traps with 35% moisture.

iii) The emergence of the new generation adults from the traps with 28% moisture was 382 min after the completion of emergence of the traps with 33% moisture.

iv) The new adult insects from the traps with 25% moisture emerged 140 min after the completion of emergence from the traps with 28% moisture.

v) There was a 683 min delay in the emergence of the new adults from the traps with 18% moisture

Mean emerg. time from the group traps with 16% inside moisture 1577.333 (min)	Mean emerg. time from the group traps with 18% inside moisture 1349.5 (min)	Mean emerg. time from the group traps with 25% inside moisture 643.833 (min)	Mean emerg. time from the group traps with 28% inside moisture 479.25 (min)	Mean emerg. time from the group traps with 33% inside moisture 72.917 (min)	Mean emerg. time from the group traps with 35% inside moisture 20.833 (min)	Mean emerg. time from the group traps with 40% inside moisture 2.583 (min)	Trap groups
0	227.833	933.5	1098.083	1504.416	1556.5	1574.75	with inside moisture 16%
	0	**705.667**	870.25	1276.583	1328.667	1346.917	with inside moisture 18%
		0	164.583	570.916	623.00	641.25	with inside moisture 25%
			0	406.333	458.317	476.667	with inside moisture 28%
				0	52.084	70.334	with inside moisture 33%
					0	18.25	with inside moisture 35%
						0	with inside moisture 40%

TABLE 2. Differences between the mean exit time of the emerging new adult insects among trap groups of different inside moisture

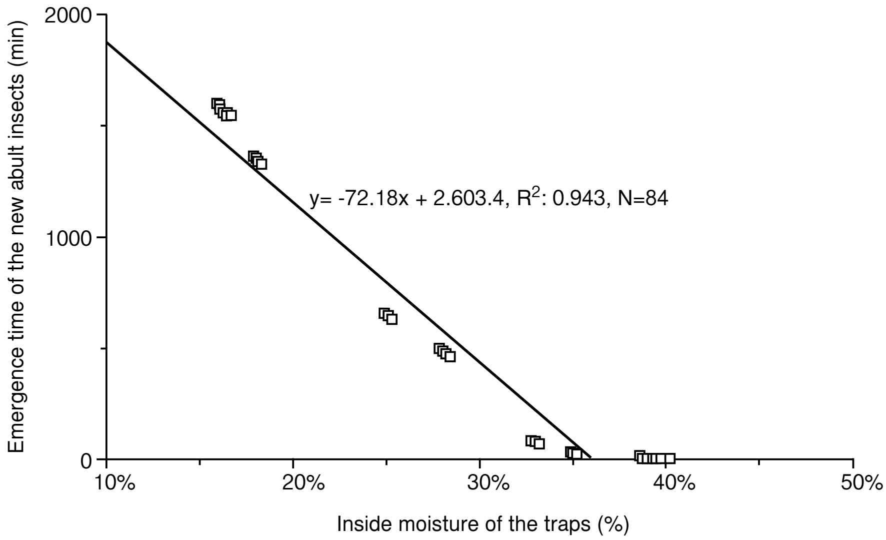

FIG. 1. Graphical representation of the percentage of inside moisture of traps (%) in relation to time of exit (in min) and flight of new adult insects.

compared to the traps with 25% moisture, and

vi) The emergence of the new generation insects from the traps with 16% moisture was 188 min after the completion of emergence from the traps with 18% moisture.

The emergence time of the new adult insects varied in the different groups of traps. Thus, in the group traps of 40%, this time was 4 min, in the 35% 12 min, in the 33% 16 min, in the 28% 30 min, in the 25% 22 min, in the 18% 27 min, and in the 16% 50 min (Table 1).

Statistical analysis with the Kruskall - Wallis H-test ($H = 81.331$, $df = 6$, $P < 0.001$) (Table 1) showed that there is a statistically significant difference in the time of emergence and flight of the new insects in the seven trap groups.

The difference between the mean (emergence time) values of pairs of traps was calculated with the Tukey W-test. The statistical analysis showed that the differences between the mean (emergence time) values (Table 2) compared to the calculated value W = 13.8418 (Table 1) were statistically significant.

The confidence limits of the difference of the mean emergence time of pairs of traps with different inside moisture were resulted from the formula: [Difference average values X - Tukey (W) < difference average values X (Table 2) < difference average values X + Tukey (W)]. E.g. the mean value of emergence time of the group with 18% inside moisture - the mean value of emergence time of the group with 25% (1349.5 min - 643.833 min = 705.667 min) (Table 2). Thus, the confidence limits for this difference resulted from the formula: 705.667 min - 13.8418 min < 705.667 min (Table 2) < 705.667 min + 13.8418 min or 691.8252 min < 705.667 min < 719.5088 min. Consequently, the limits were formed to be 691.8252 min the lower confidence limit and 719.5088 min the upper confidence limit.

The relationship between the inside moisture of the traps and the time of emergence and flight of the new adult insects was linear, it had a negative gradient and it was expressed by the equation: $y = -72.18x + 2603.4$, R^2: 0.943, ($N = 84$) (Curve fit: First order polynomial) (Fig. 1).

Experiment II. Mean diameter and bark thickness of the traps and emergence time of the new adult insects of C. vestitus

Some of the used branchtraps were destroyed and the remaining (30) were grouped into two groups, of fifteen traps each, according to their diameter and bark thickness.

Table 3 shows the differences in the emergence and flight time of the new generation insects of *C. vestitus* in branchtraps of different diameter and bark thickness, but of almost the same inside moisture.

The biggest diameter and bark thickness in the group of traps was 3.00 cm and 5.00 mm, respectively (2.964 cm ± 0.138 and 4.928 mm ± 0.125) and the smallest one was 2.00 cm and 3.00 mm (2.043 cm ± 0.103 and 2.902 mm ± 0.081). To determine the

TABLE 3. Diameter (cm) and bark thickness (mm) of traps and corresponding emergence time (min) of the new adult insects

Morph. Character. Traps. M.V.Diameter traps ± S.D. (Min. - Max.) M.V.cor.bark- thickn. ± S.D. (Min. - Max.)	Number of traps in each group	Mean. values Emerg. time ± S.D. (min)	Emerg. time Min. - Max. (min)	Range time (min)	Statistical analysis
Group A: Diam. 2.964 cm ± 0.138 (2.74 - 3.2 cm) Thick. 4.928 mm ± 0.125 (4.7 - 5.08 mm)	15	122.533 ± 9.334	107 - 136	29	1. Variance f- test = 1.4507 1.4507< 2.5436 and P = 0.05
Group B: Diam. 2.043 cm ± 0.103 (1.9 - 2.22 cm) Thick. 2.902 mm ± 0.081 (2.77 - 3.01 mm)	15	11.533 ± 7.671	1 - 25	24	2. T- test t = 6.338 with df = 29 and P=0.0001

emergence time of the new adults we considered (scored) as 1 min the time that the first new generation of insects exited from the traps with the smallest diameter and bark thickness (1.90 cm and 2.77 mm), correspondingly (Table 3).

From the difference between the minimum emergence time from the group of traps with big diameter and bark thickness and the maximum emergence time from the group of traps with small diameter and bark thickness (Table 3), it follows that the new adult insects from the group of traps with big diameter and bark thickness emerged 82 min after the completion of emergence from the group of traps with small diameter and bark thickness.

Thus, for the traps with 2.00 cm diameter and 3.00 mm bark thickness, the minimum emergence time was 1 min, while for the traps with 3.00 cm diameter and 5.00 mm bark thickness it was 107 min. Data showed that there was a delay of 111 min in the mean (emergence time) value, between the traps with 3.00 cm diameter and 5.00 mm bark thickness and those with 2.00 cm diameter and 3.00 mm bark thickness (Table 3). The emergence time of the new adult insects varied in the different groups of traps. Thus, in the traps with 2.00 cm diameter and 3.00 mm bark thickness it was 24 min, while in the traps with 3.00 cm diameter and 5.00 mm bark thickness 29 min (Table 3).

Analysis of variance ($f = 1.4507 < 2.5436$, $P = 0.05$) and T-test ($t = 6.338$, $df = 29$, $P = 0.0001$) (Table 3) showed statistically significant differences between the mean emergence time of the new adult insects of two compared trap groups (of almost the same inside moisture but different diameter and bark thickness).

DISCUSSION AND CONCLUSIONS

Experiment I. Inside moisture of the traps

The bark beetle *C. vestitus* is an inportant insect which attacks mainly twigs and branches of *Pistacia* species (Mourikis *et al.*, 1998). That is why cut and dead branches must be removed from the orchards.

By interpreting the negative gradient of the linear relationship between the percentage of inside moisture of the traps and the time of emergence and dispersal flight of the new adult insects, it is concluded that, while the inside moisture increased, the time of the excavation emergence through the bark, exit and flight of the newly emerged adults decreased.

All the differences of exit times of new adult insects among the compared trap groups (different percentages of moisture) that are reported in Table 1, confirm the conclusion of a more rapid exit and flight of the new adult insects from the traps with higher inside moisture or a delayed exit and flight from the traps with lower inside moisture.

The increased moisture of the traps selected for reproduction contributed to the rapid development of the evolving stages of the life cycle of *C. vestitus*. This was attributed to the fact that feeding of the larvae took place more easily, the excavation of the larval galleries and larval cribs were facilitated and finally the developmental completion of the pupae was expedited. Furthermore, the perforation of the bark by the newly emerged adults was facilitated and resulted in the expediting of the excavation emergence through the bark and their exit to the outside. The above mentioned factors contributed to a faster dispersal flight.

The increase of the inside moisture of the traps, up to a limit, expedited the exit and flight of the new adult insects. The maximum limit of this increase was placed beyond the experimentally found maximum terminal value of 40.225% (Table 1), and it probably reached the level of about 45%. However, there is no experimental confirmation for the latter.

Observations on very wet, cut branches of the host tree *Pistacia vera* L., revealed rot, intense fungal infections and parasitism on *C. vestitus*, caused by other insects and arachnoids. In conclusion, in cases of inside moisture much higher than the above mentioned values it is very likely that the capability of the species for a successful emergence is lost.

Experiment II. Diameter and bark thickness of the traps

It was found that the increase of trap diameter was always accompanied by a corresponding increase of the bark thickness. This incident justifies the linear relationship between the ratio diameter / bark thickness of the traps and the emergence time of the new adult insects.

The differences in the time of exit and flight of the new adult insects between the compared trap groups, led to the following conclusion: The excavation emergence through the bark, the exit and the dispersal flight of the new adults took place rapidly in the traps with smaller diameter and bark thickness, and slowly in the traps with greater diameter and bark thickness.

The trap bark was considered as an essential factor influencing the emergence of the new generation insects, because when it was thin, the environmental temperature and the more easily absorbed solar radiation increased bark heat. Thus, larvae and pupae predisposed from this increase, expedited their developmental completion and the newly metamorphosed aduls expedited their excavation emergence through the bark with consequence their more rapid exit and dispersal flight. It is also obvious that the perforation time of a thin bark is shorter than that of a thick bark. This fact explains the more rapid emergence and dispersal flight of the new adults of *C. vestitus* from the thinly barked traps.

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