Drewno 2019, Vol. 62, No. 204
DOI: 10.12841/wood.1644-3985.293.11

Adam KRAJEWSKI, Piotr WITOMSKI, Anna OLEKSIEWICZ

THE IMPACT OF AIR RELATIVE HUMIDITY ON THE LENGTH OF LIFE OF THE BEETLE *LYCTUS BRUNNEUS*

Research was conducted on the life length of adult Lyctus brunneus Steph. beetles [Coleoptera: Bostrichidae; Lyctinae] under laboratory conditions with air relative humidity in the range 25-30% and above 90%. Both tested groups of adults were kept at a temperature of 23 ±1°C. The average life length of adult insects was 6.2 days in dry air conditions and 18.1 days in humid air conditions. The difference of 11.9 days is statistically significant. Apart from the statistically significant impact of air relative humidity on the life length of adults, the impact of another factor was detected. It may be assumed that parasites played an important role, also causing a reduction in the body length of adults of L. brunneus.

Keywords: *Lyctus brunneus*, powder post beetles, air humidity, life length of insects

Introduction

Lyctus brunneus (Steph.) [Coleoptera: Bostrichidae; Lyctinae] is listed as one of the most dangerous species of wood boring insects. This cosmopolitan species is widespread in all warm and moderate climate zones [Weinder 1967; Borowski and Węgrzynowicz 2007]. It is believed to originate most probably from the Indo-Malaysian region [Dominik and Starzyk 2004] or South America [Cymorek 1961]. As is the case with the closely related *L. africanus*, it is nearly impossible to trace the species to its area of origin [Halperin and Geis 1999]. Among insects, only the old house borer (*Hylotrupes bajulus* L.) and termites cause greater problems in Europe by destroying the wood of structures [Dominik and Starzyk 2004; Krajewski et al. 2015; Nowakowska et al. 2017].

Recently, the former family Lyctidae (including the discussed species) has been reclassified as the subfamily Lyctinae (Billberg, 1820) of the family Bostrichidae (Latreille, 1802) [Borowski and Węgrzynowicz 2007]. The view of *Lyctus brunneus* as a dangerous wood boring insect, however, remains unchanged [Weidner 1967; Adlbauer 1998; Dominik and Starzyk 2004].

Adam KRAJEWSKI✉ (*adam_krajewski@sggw.pl*), Piotr WITOMSKI (*piotr_witomski@sggw.pl*), Anna OLEKSIEWICZ (*anna_oleksiewicz@sggw.pl*), Warsaw University of Life Sciences, Faculty of Wood Technology, Poznan, Poland

L. brunneus feeds on European wood species of industrial importance – oak, ash, elm, walnut – as well as many tropical species [Dominik and Starzyk 2004]. It is believed that beech (*Fagus sylvatica* L.) wood is not attacked by *Lyctus brunneus* because of the low starch content in the wood [Cymorek 1975]. *L. brunneus* is the most important pest of light-coloured tropical timbers, and is transported to Europe within the wood [Weidner 1967; Adlbauer 1998; Halperin and Geis 1999; Dominik and Starzyk 2004; Krajewski and Mazurek 2010]. In the second half of the 19th century and the first decade of the 20th century, *L. brunneus* was introduced sporadically into several European countries for the first time, but it became established only in England and Wales. In continental Europe, it was introduced during the two decades after the Second World War, particularly in Germany and neighbouring central European countries [Adlbauer 1998; Halperin and Geis 1999; Bussler 2009]. It is believed that it is most probably established in Poland as well [Dominik and Starzyk 2004], as it is able to survive long but moderate winters [Cymorek 1970].

L. brunneus is considered a dangerous threat to wood for two reasons: its short period of development, and the ability of larvae to survive in very dry wood. Peters et al. [2002] report that the development period for larvae ranges from 2 to 18 months, but under adverse conditions the life cycle may last from 30 to 40 months or longer. Dominik and Starzyk [2004] observe similarly that the development of one generation most typically lasts around one year. However, given a high starch and protein content in the sapwood, in heated rooms during winter, this can be reduced to about four months. Most of the insect's life consists of the larval stage. Wood damage is caused by larvae of *L. brunneus*, developing in sapwood with a very low moisture content of 5.5-23.5%, with optimal value of 14% [Parkin 1943]. The moisture content of the wood most commonly attacked by *L. brunneus* is estimated at around 8-10% [Bussler 2009]. The ability to develop in such dry wood is not exhibited by other dangerous European wood boring insects, such as *Anobium punctatum* De Geer (Coleoptera: Anobiidae) or even *Hylotrupes bajulus* L. (Coleoptera: Cerambycidae).

Because of this far-reaching degree of adaptation of *L. brunneus* larvae to a dry environment, the question arises whether adult insects, living outside the wood, are also as undemanding in terms of air relative humidity as the larvae – especially since the literature describes wood attacked by the species in rooms heated during the winter [Dominik and Starzyk 2004], where the air relative humidity is very low. By comparing the life lengths of two test groups of adults of *L. brunneus*, observed in environments with different air relative humidity, it may be determined whether the adults are as resistant to a dry environment as the larvae, and how great is the impact of air humidity on adult *L. brunneus* life length. This was the objective of the experiment described below, concerning the life length of adults of *L. brunneus* under conditions of different air humidity, with the assumption that two groups of results would be obtained, both described by a Gaussian curve, but shifted in the X-axis.

Materials and methods

The opportunity to observe this invasive species of insect was provided by a Polish wood-trading company, which imported samba wood (*Triplochiton scleroxylon* K. Schum: Sterculiaceae) from western Africa and supplied it to the Department of Wood Sciences and Wood Protection. The surface of the wood was already covered with numerous holes, bitten out by adults of *L. brunneus*. More adults of that species were still emerging from the wood, and these were used in the experiment.

Adult insects, appearing on the surface of the wood, were successively caught and placed in turn into conditions with air relative humidity of 25-30% and with air relative humidity above 90%. Each adult insect was placed on a Petri dish with a diameter of 50 mm, covered with filter paper. The conditions of increased humidity were supplied by a wet ball of filter paper, placed on a glass pad. Every day the wet ball was replaced with a new one. Each Petri dish was covered with a lid. Each of the observed groups consisted of 38 adult insects.

Both groups of *L. brunneus* adults were kept at a temperature of 23 ±1°C. Every day the numbers of living and dead individuals were recorded, along with the number of days they had survived.

Due to the unexpected deviation of the distribution of life lengths of the beetles from a normal distribution, in both groups, the evaluation of the statistical significance of the difference between average life lengths in wet and dry environments required an appropriate test for such a situation. For that reason, Chebyshev's inequality was used to evaluate the significance of mortality in each variant of the experiment. If the absolute value of the difference of arithmetic mean values of mortality in both insect groups $\left[|\bar{x}_1-\bar{x}_2|\right]$ was greater than or equal to triple the value of the standard error of the difference $\left[3(\bar{x}_1-\bar{x}_2)\right]$, i.e.:

$$\left[|\bar{x}_1-\bar{x}_2|\right] \geqslant 3\cdot\varepsilon(\bar{x}_1-\bar{x}_2)$$

then the difference of the mean values was recognised as statistically significant. Otherwise, it was considered accidental.

However, as the results obtained had been clearly deformed by an unidentified factor, a preliminary attempt was made to explain the significance of that unexpected phenomenon. In both groups, 124 adults of *L. brunneus* which had left the wood were measured. This number included all of the individuals used in the experiment. The conformity of the statistical distribution of body length to a normal distribution was evaluated using Pearson's chi--squared test, where:

$$\chi^2 = \frac{(n_1 - n_1')^2}{n_1'} + \frac{(n_2 - n_2')^2}{n_2'} + \ldots + \frac{(n_s - n_s')^2}{n_s'}$$

χ^2 – Pearson's criterion
n_1, n_2, n_s – number of individuals in each class
n'_1, n'_2, n'_s – theoretical frequency of respective classes
s – number of classes

If $\chi^2 \geq 3$, the difference between the obtained statistical distribution and a normal distribution is considered significant.

The number of holes on the surface of the samba wood was also counted. The number of holes left by adult insects in the two areas with the highest density of holes (a total area of 20 cm^2) was also recorded. The number of holes per cm^2 was calculated for the whole surface of the wood, as well as for the areas with the highest density. Also, the average volume of wood per adult insect was calculated.

Results and discussion

The results for the life length of the beetles in both test groups are shown in table 1.

Table 1. Life length of *L. brunneus* adult insects living under conditions of low and high humidity at a temperature of 23 ±1°C

Life length of adults [in days]	Number of adults living in air relative humidity 25-30%	Number of adults living in air relative humidity above 90%
1-3	17	7
4-6	9	1
7-9	3	0
10-12	2	5
13-15	3	4
16-18	3	1
19-21	1	6
22-24	0	1
25-27	0	3
28-30	0	3
31-33	0	3
34-36	0	2
37-39	0	1
40-42	0	1
	Total: 38 individuals	Total: 38 individuals

The results for life length of adult *L. brunneus*, shown in the table on a three-day scale, were additionally regrouped on a six-day scale and are shown in figure 1 to visualise the phenomenon more clearly.

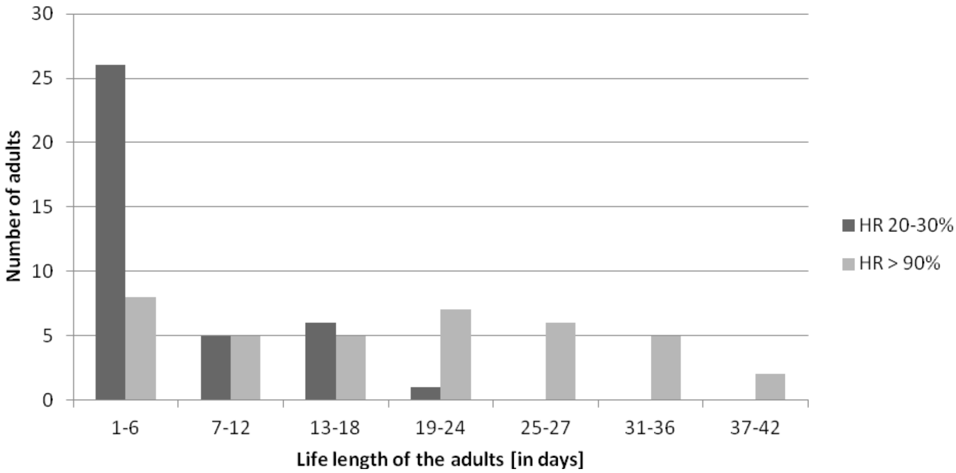

Fig. 1. Life length of *L. brunneus* adults in air relative humidity 25-30% and in air relative humidity above 90%.

The average life length of adult insects in the dry environment was 6.2 days, while the average life length of adult insects in the humid environment was 18.1 days. A statistically significant difference of 11.9 days was obtained between average life lengths of adult insects in the two groups $[|\bar{x}_1 - \bar{x}_2|]$. This difference was larger than three times the standard error of the difference between the average values $[3(\bar{x}_1 - \bar{x}_2) = 6.2]$.

The results for the body lengths of randomly selected beetles are shown in table 2.

Table 2. Body lengths of *L. brunneus* adult insects

Body length [mm]	Number of adults
2.5-2.7	7
2.8-3.0	34
3.1-3.3	29
3.4-3.6	22
3.7-3.9	12
4.0-4.2	9
4.3-4.5	5
4.6-4.8	3
4.9-5.1	1
5.2-5.5	2

It was ascertained that the value of χ^2 did not exceed or even reach 3. It was thus concluded that the distribution of the beetles' body lengths did not differ significantly from a normal distribution.

The piece of samba wood used to obtain adult insects of *L. brunneus* had a volume of 1138 cm^3 and a surface area of 915 cm^2. The total number of holes left by the beetles on the surface of the wood was 320. Thus, the beetles caught and used in the experiment constituted only about one-third of the total number. The density of holes left by the beetles was about 0.35 holes per cm^2. In the areas with the largest density of holes, the density reached 1.9 holes per cm^2. The average volume of samba wood per adult was 3.6 cm^3. This indicates a very high *L. brunneus* population density in the wood used in the experiment. It has to be taken into account that the calculated density refers only to individuals which reached the imago stage and left the wood. The number of insects which died as larvae, pupae or imagines inside the wood remains unknown.

Different stages of insect development have different needs in terms of air humidity. The duration of development of eggs of *L. brunneus* is 6-7 days at a temperature of 26°C and 12-20 days at a temperature of 15-20°C (Dominik and Starzyk 2004). The air humidity plays a less significant role in the process.

Larvae of *L. brunneus* are among the wood-destroying insects able to adapt to extremely low wood moisture contents. Various authors give similar data, though differing in details, on the moisture content of wood in which larvae are able to grow: 5.5-23.5% [Dominik and Starzyk 2004], 8-25% [Parkin 1943; Bootle 1983; Peters et al. 2002], or 8-30% [Liu et al. 2008]. Howick [1968] suggested a more restricted range of 10-20%. Bussler [2009] states that the minimal value enabling the development of larvae is 7-8%. The optimal moisture content for larvae of *L. brunneus* is estimated at 14% [Dominik and Starzyk 2004] or 15% [Peters et al. 2002]. Few wood boring insects in Europe match *L. brunneus* in this respect. Among the most dangerous wood boring insects, in the case of the old house borer (*Hylotrupes bajulus* L.: Coleoptera: Cerambycidae) the minimal value of wood moisture for the development of larvae is around 8-10%, and in the case of common furniture beetle larvae (*Anobium punctatum* De Geer: Coleoptera: Anobiidae) it is around 15% or more. Also, the optimal value of wood moisture for both species is around the saturation point for the fibres, i.e. 28–30% [Dominik and Starzyk 2004].

Moisture content in the bodies of insects living in wood in the wild typically ranges from 70% to 95%. Most species of insects living in buildings do not regularly feed on food with a moisture content lower than 30%. Larvae of *Stegobium paniceum* L. (Coleoptera: Anobiidae) consume food with a 6-15% moisture content, and the moisture content of their bodies is estimated at 58.9% [Van Emden 1929]. The larvae of some species of clothes moths (Lepidoptera: Tineidae) consume food of around 10% moisture content, while the moisture content of their bodies is even lower than that of the aforementioned species, at around 52.2%, falling to as low as 42% [Van Emden 1929].

Adults of the old house borer and the common furniture beetle, bred in laboratory conditions, always attach to wet balls of filter paper, which suggests that they require a highly humid environment. Similar behaviour was observed with *L. brunneus* adults. The results of the experiment show the importance of the environment to adults of wood boring insects, even those which developed as larvae in relatively dry wood.

The statistical distribution of life lengths of *L. brunneus* adults, differing from a normal distribution, clearly points to an additional factor apart from the relative humidity of air. In spite of that additional factor, the results prove that adults of *L. brunneus* exhibit a higher demand for humidity of the environment than the larvae, which have adapted to life and development in very dry wood. Almost all of the adults of *L. brunneus* kept under conditions of air relative humidity between 25% and 30% were dead after three weeks, and the last individual died after six weeks. The average life length of adults of *L. brunneus* with air relative humidity above 90% was three times greater than when the humidity was 25-30%. It should be noted that according to Dominik and Starzyk [2004] the average life length of *L. brunneus* adults is around two weeks. Liu et al. [2008] report that adults of *Lyctus* sp. can live longer than 30 days. In the present experiment, under high humidity conditions, 20 individuals (53% of the test group) lived longer than 15 days, 11 individuals lived longer than 30 days, and 1 individual lived as long as 41 days. Under conditions of air humidity between 25% and 30%, only 4 individuals (around one-tenth of the group) lived longer than 15 days.

It has long been known that female adults of *L. brunneus* bite the surface of wood [Parkin 1936; Bletchly 1960; Dominik and Starzyk 2004]. Experiments conducted by Kartika and Yoshimura [2013] on the related species *L. africanus* (Col.: Bostrichidae) prove that starch and sugar are vital nutrients for *L. africanus* (Lesne) and may attract adult females to lay their eggs. Also, diet composition is suggested to influence the fecundity of adults of *L. africanus*. Polysaccharides consumed and digested by female adults of *Lyctus* sp., as well as *L. brunneus*, undoubtedly allow them to supplement (at least to a certain degree) the water stored in their bodies.

Under experimental conditions, the only source of water for the adults of *L. brunneus* were the wet balls of filter paper. The water was either licked from the balls or absorbed through stigmas in the form of steam. All individuals sat on the wet balls. In the experiments, adult insects in the environment of 90% air relative humidity had no opportunity to feed on appropriate material to supplement the water in their bodies by digesting starch and sugar from the food.

Adult insects living in the extremely unfavourable environment of 25-30% air relative humidity had no opportunity to feed or to supplement the water in their bodies even by absorbing steam through stigmas. Although all individuals sat in gaps in the balls, they could use them only as a form of shelter.

The wood of *Triplochiton scleroxylon* is known as samba, and locally or in trade also as obeche, wawa, ofa, sam, ayous, aréré or obechi. The organisms primarily listed in the literature as causing degradation of samba wood are Bostrichidae (Col.) including Lyctinae, and Cerambycidae (Col.), as well as molluscs (Mollusca: Lamelibranchiata; Teredinidae and Pholadidae) [Wagenführ and Scheibler 1989]. The presence of *L. brunneus* in samba wood is thus not unexpected. The average volume of wood per adult insect leaving the investigated piece of samba wood was 3.6 cm^3, which indicates a very large population density, given that numerous individuals may have died earlier in the larval or pupal stages. In the places with the largest density, 38 holes were found in an area of 20 cm^2 (two holes per cm^2). Such a large density of individuals in the larval stage of development favours predator and parasite attacks. Predator species previously reported as attacking larvae of *L. brunneus* include *Tetreus picipes* F. (Coleoptera: Histeridae) and *Tarsostenus univitatus* Rossi (Col.: Cleridae) (Thompson and Simonds 1965). However, in the investigated piece of samba wood no other insect (or arthropod) species was identified apart from *L. brunneus*.

It seems that the cause of the anomalies in life lengths of the *L. brunneus* adults in the experiment, and of the large number of individuals living for a relatively short time, is probably an internal parasite, such as a microorganism or nematode. No information was found in the literature in this regard. It seems that such parasites may reduce the population and limit the spread of this dangerous wood boring insect in the same way that saprobionts significantly reduce the population of the common furniture beetle. The identification of parasites of *L. brunneus* and their impact on the invasive abilities of this dangerous wood boring insect requires further research, going beyond the preliminary stage of experiments conducted by the authors.

The activity of the presumed parasite, significantly reducing the life lengths of *L. brunneus* adults, did not cause a deviation from the normal distribution of body lengths of the tested individuals. A normal distribution of body lengths was also observed for a group of adults of the related species *Lyctus planicollis* Le Conte (Col.: Bostrichidae), not attacked by parasites [Kurir 1969]. The adults are up to 7 mm long [Hickin 1963; Peters et al. 2002], but most often their body lengths range from 3 to 5 mm [Dominik and Starzyk 2010]. However, for the tested group of adults of *L. brunneus*, as many as 78% were placed in the 2.5-3.6 mm class, with a peak between 2.8 and 3.3 mm. It seems that not only the trophic factor, but also the presumed internal parasite, resulted in shorter body lengths.

Conclusions

The results of the experiment lead to the following conclusions concerning factors reducing the spread of *L. brunneus*.

A dry air environment, typical of the interior of buildings heated in winter (which is standard in Europe nowadays), causes reduction in the life lengths of adult insects, down to as little as one-third of the length of life in a humid air environment, even though the larvae are adapted to living in very dry wood.

In the experiment, another factor was visible having a serious impact on the life lengths of *L. brunneus* adults. It may be assumed that with a large density of individuals in the wood, larvae and pupae of *L. brunneus* can be severely attacked by parasites, which can lead to the faster extinction of a large number of adults, and to a large number of shorter individuals emerging from the wood.

References

Adlbauer K. [1998]: Die Splintholzkäferfauna der Steiermark (Coleoptera, Lyctidae), Mitteilungen Landesmuseum Joanneum 51: 55-58

Bletchly J.D. [1960]: Studying the egg of *Lyctus brunneus*. Timber Technology 68: 30-31

Bootle K.R. [1983]: Wood in Australia – types, properties and uses. McGraw-Hill Book Company, Sydney, Australia

Borowski J., Węgrzynowicz P. [2007]: World catalogue of Bostrichidae (Coleoptera). Wydawnictwo MANTIS, Olsztyn

Bussler H. [2009]: Teures Leben im Parkett. Eingeschlepte Splintholzkäf zählen zu den bedeutendsten Schädlingen von Holzprodukten. LWF aktuell 73, [in] Neue Arten, 18-19

Dominik J., Starzyk J.R. [2004]: Owady uszkadzające drewno. PWRiL, Warszawa

Dominik J., Starzyk J.R. [2010]: Atlas owadów uszkadzających drewno. MULTICO Oficyna Wydawnicza, Warszawa

Cymorek S. [1961]: Die in Mitteleuropa einheimischen und eingeschlepten Splintholzkäfer aus der Familie Lyctidae. Entomologische Blätter 57 76-102

Cymorek S. [1970]: Eingeschleppte und einheimische Bohr- und Splintholzkäfer als Holzschädlinge (Col.: Bostrychidae, Lyctidae). Zeitschrift für angewandte Entomologie 66, 206-224

Cymorek S. [1975]: Zur Immunität von Rotbuchenholz (*Fagus sylvatica* L.) gegenüber Befall durch *Lyctus bruneus* Steph. und *Lyctus africanus* Lesne (Col. Lyctidae). Material und Organismen 3: 441-446

Halperin J., Geis K.-U. [1999]: Lyctidae (Coleoptera) of Israel, Their Damage and Its Prevention. Phytoparasitica 27 [4]: 257-262

Howick C.D. [1968]: Common borers in building timbers. Part IV. Bostrychid borers – "Auger" beetle. CSIRO Forest Products Newsletter 348

Kartika T., Yoshimura T. [2013]: Nutritional quality of diet and fecundity in *Lyctus afrikanus* (Lesne). Procedia Environmental Sciences 17: 97-104

Krajewski A., Mazurek A. [2010]: Exotic species of wood borers in investigations of Wood Protection Division SGGW in Warsaw in years 1997-2009. Annals of WULS, Forestry and Wood Technology 71: 395-399

Krajewski A., Lisiecka E., Drożdżek M., Witomski P. [2015]: The susceptibility of neolithic waterlogged beech wood (*Fagus sylvatica* L.) to destruction by Reticulitermes lucifugus Rossi. Drewno. Prace Naukowe, Doniesienia, Komunikaty 58 [195]: 59-68. DOI: 10.12841/wood. 1644-3985.113.05

Kurir A. [1969] Beitrag zur Taxonomie und Biologie des Amerikanischen Splintholzkäfers (*Lyctus planicollis* Le Conte). Zeitschrift für angewandte Entomologie 63: 62-92

Liu L.-Y., Schönitzer K., Yang J.-T. [2008]: A review of the literature on the life history of Bostrichidae (Coleoptera). Mitteilungen der Münchner Entomologischen Gesellschaft 98: 91-97

Nowakowska M., Krajewski A., Witomski P. [2017]: The relationship between the masses of old house borer larvae (*Hylotrupes bajulus* L.) and their lengths measured on radiograph. Drewno. Prace Naukowe, Doniesienia, Komunikaty 60 [199]: 81-88. DOI: 10.12841/wood. 1644-3985.201

Parkin E.A. [1936]: A study of the food relations of the *Lyctus powder* – post beetles. Annals of Applied Biology 23: 369-400

Parkin E.A. [1943]: The moisture content on timber in relation to attack by *Lyctus poweder* – post beetles. Annals of Applied Biology 30 136-142

Peters B.C., Creffield J.W., Eldridge R.H. [2002]: Lyctidae (Coleoptera: Bostrichidae) pests of timber in Australia: A literature review and susceptibility testing protocol. Australian Forestry. June: 107-114

Thompson W.R., Simonds E.J. [1965]: A catalogue of the parasites and predators of insect pest. Farnaham Royal

Van Emden F. [1929]: Über die Rolle der Feuchtigkeit im Leben der Speicherschädlinge. Anzeiger für Schädlingskunde 5: 58-60

Wagenführ R., Scheibler C. [1989]: Holzatlas. VEB Fachbuchverlag, Leipzig

Weidner H. [1967]: Insektenschäden an Souvenirs aus fernen Lädern. Zeitschrift für angewandte Entomologie 4 [40]: 57-60

Submission date: 25.06.2018

Online publication date: 12.11.2019