This is an author produced version of a paper published in Physiological Entomology. This paper has been peer-reviewed but may not include the final publisher proof-corrects or pagination.

Citation for the published paper:

Access to the published version may require journal subscription. Published with permission from: Wiley.

Standard set statement from the publisher:
This is the accepted version of the following article: Fedderwitz, F., Björklund, N., Ninkovic, V. & Nordlander, G. (2014) Diel behaviour and time budget of the adult pine weevil, Hylobius abietis. Physiological Entomology, 39, 103-110, which has been published in final form at: http://dx.doi.org/10.1111/phen.12053.

Epsilon Open Archive http://epsilon.slu.se
Diel behaviour and time budget of the adult pine weevil, *Hylobius abietis*

Frauke Fedderwitz¹, Niklas Björklund, Velemir Ninkovic and Göran Nordlander

Department of Ecology, Swedish University of Agricultural Sciences, Box 7044, SE-750 07 Uppsala, Sweden

¹ Corresponding author: frauke.fedderwitz@slu.se

Correspondence: Frauke Fedderwitz, Department of Ecology, Swedish University of Agricultural Sciences, Box 7044, SE-750 07 Uppsala, Sweden. Tel.: 0046(0)18-672312; e-mail: frauke.fedderwitz@slu.se
Abstract

The pine weevil (*Hylobius abietis* (L.); Coleoptera: Curculionidae) has a high economic impact on forest regeneration in Europe. The general biology of the pine weevil has received considerable attention, but there is insufficient knowledge about its diel behaviour and time budget. Therefore, the feeding and locomotion behaviour of individual adult weevils on Norway spruce (*Picea abies* (L.) Karst.) seedlings is observed for 24 hour-periods in the laboratory. Both girdled and non-girdled seedlings are used to assess how the weevils’ behaviour is influenced by the plants physiological response to the girdling. The locomotion pattern shows a distinct maximum during the beginning of the dark phase whereas most feeding occurs during the second half of the dark phase and the first hours of the subsequent light phase. The girdling treatment increase the time that weevils spend on the seedlings during the first part of an observation session, but has no effect on their feeding pattern. The weevils’ time budgets on girdled and non-girdled seedlings are similar. On average, they spend 34 % of their time in locomotion and 6 % on feeding. Females spend more time feeding than males (7.1 % vs. 4.2 %), possibly because they have higher food requirements, e.g. for egg production. Females also spend more time in total on the seedlings than males (26.3 % vs. 7.0 %). This study reveals, in high temporal resolution, the diel feeding and locomotion behaviour and time budget of male and female pine weevils.

Keywords: chronobiology, circadian, conifers, daily rhythms, diurnal, herbivore, plant-insect interactions, photoperiod, sex differences
Introduction

Diel rhythms allow organisms to prepare for periodic changes in environmental conditions, e.g. onset of darkness. They are also affecting trophic relations and thus influencing survival chances of predators and prey (Harmsen et al., 2011). Even on an intraspecies level synchronisation of diel rhythms is important (Danilevsky et al., 1970). For example, females of different pyralid moth species call during the beginning or end of the dark phase (Zavodska et al., 2012), which are common periods of high insect activity (Danilevsky et al., 1970). The males of these species have high locomotion activity during the respective periods which increases chances in mate locating (Zavodska et al., 2012). Other examples of diel rhythms include, the apple blossom weevil (Anthonomus pomorum L.) and Warren rootcollar weevil (Hylobius warreni Wood), which are mostly active and feed during dark phases, whereas they rest during light phases (Cerezke, 1994; Duan et al., 1996). In addition, both H. warreni and Hylobius xiaoi (Zhang) show distinct diel movement patterns, ascending trees at dusk and descending at dawn (Cerezke, 1994; Wen et al., 2004).

In the present study, the diel behaviour of the pine weevil (Hylobius abietis (L.) (Coleoptera: Curculionidae)), an economically important forest pest species, is investigated. The pine weevil is distributed over large parts of Europe and Asia. It feeds on tender bark of several conifer species, e.g. Scots pine (Pinus sylvestris L.) and Norway spruce (Picea abies). Pine weevils reproduce in the roots of recently killed or dying conifer trees, which occur at high densities in man-made clear-cuts and after storm fellings or forest fires (Eidmann, 1974). The weevils disperse to suitable areas for reproduction by long-distance migratory flight in spring and early summer (Solbreck & Gyldberg, 1979). Host volatiles emitted from stumps and dying trees guide
the flying weevils to suitable sites, and soon after they have settled their wing muscles
degenerate (Nordenhem, 1989). Walking weevils use both visual and olfactory cues to locate
conifer seedlings (Björklund et al., 2005). Although weevils feed mostly on bark of roots and
twigs of mature conifer trees, it is the feeding on the stem bark of seedlings that cause the
economic losses (Wallertz et al., 2006; Örlander et al., 2000). Damages to seedlings may cause
mortality of up to 90 %, mostly due to girdling (Långström & Day, 2004; Petersson & Örlander,
2003).

Under laboratory conditions locomotion behaviour of pine weevils is highest at the beginning of
dark phases and decreases towards the end of dark phases or after the onset of light phases
(Merivee et al., 1998; Pszczolkowski & Dobrowolski, 1999). Under field conditions their
locomotion is also influenced by ambient temperature and humidity, which are generally most
favourable at twilight (Sibul et al., 1999). They feed mainly during dark phases under field
conditions, but under semi-field conditions in shaded cages and laboratory conditions their
feeding activities has not been demonstrated to show any obvious temporal pattern (Christiansen
& Bakke, 1971; Merivee et al., 1998).

Diel patterns are also expressed in plants, e.g. in photosynthesis activity and volatile emission
(Lüttge & Hertel, 2009; Staudt et al., 1997). It is recently reported that the diel regulation of an
induced plant’s defence is synchronized with temporal patterns of its herbivores’ feeding
behaviour (Goodspeed et al., 2012). Damages to conifer seedlings, like girdling, a typical
damage caused by adult pine weevils (Eidmann, 1974), cause changes in the chemical
composition of the stem and in the volatiles that are emitted (Gref & Ericsson, 1985; Martin et
Such chemical changes in seedlings due to insect damage may also influence pine weevil behaviour (Kännaste et al., 2009).

Time budgets describe the proportions of time that an animal allocates to different behaviours (Joern et al., 1986). These proportions do not necessarily reflect the importance of the behaviours but indicate the optimal solutions to environmental problems (Joern et al., 1986). Many insects, such as apple blossom weevils, Costa Rican weevils, potato beetles, carabid beetles and grasshoppers, spend most of their time resting (Drees et al., 2008; Duan et al., 1996; Joern et al., 1986; Mitchell & Low, 1994; Wright et al., 1999). Less time is allocated to feeding behaviour, ranging from just 3 % for the Costa Rican weevil up to 27 % for the Apple blossom weevil (Duan et al., 1996; Wright et al., 1999).

The aim of this study was to describe diel behaviour patterns and time budgets of adult pine weevils. Locomotion and feeding behaviour of adult pine weevils are studied on Norway spruce (Picea abies (L.) Karst.) seedlings in the laboratory under an artificial light regime using 24-h video-recordings. Because the behaviour may be influenced by the physiological condition of the seedling, the behaviours on both non-girdled and previously girdled seedlings are investigated. The behaviour of male and female weevils is also compared.

Materials and methods

Insect and plant material

The pine weevils used in the study were collected in central Sweden during spring migration a few weeks before the start of the experiment. After collection, the weevils were fed with
branches of Scots pine while kept in darkness at 10°C. These storage conditions interrupt the
reproductive development of the weevils (Bylund et al., 2004). About a week prior to their use in
the experiment the weevils were transferred to a chamber with room temperature (22°C) and the
artificial day-night-cycle (L18:D6) as was used during the experiment (see below). This
procedure synchronized the physiological state of the weevils, since mating, oviposition and
therewith associated period of high feeding activity starts soon after the transfer from storage in
darkness at 10°C (Bylund et al., 2004).

The plant material consisted of one and a half year old Norway spruce (Picea abies) seedlings
grown from seeds collected in a seed orchard and produced for plantation in central Sweden by a
commercial nursery (Sjögränd, Bergvik Skog AB). The seedlings were kept outdoors and
transferred to a chamber providing the experimental conditions a day before use.

Experimental procedure

The experiment was conducted during June to September 2011. Six male and six female pine
weevils were placed singly in a transparent plastic cylinder (height 8 cm, diameter 11 cm) that
was placed around the middle part of a spruce seedling’s stem (Figure 1). The stem base and top
shoot were not accessible to the weevil to reduce heterogeneity of the feeding source (Kaakinen
et al., 2004). Neither the connections between the parts of the cylinder nor the connection to the
seedling were airtight. Two video cameras (Sony Handycam HDR-XR550VE, Sony
Corporation, Tokyo, Japan; G lense (F 1.8-3.4; focal length: f 3.8-38 mm)) were then focused on
the seedling, set at 45 ° to each other to ensure high visibility of weevil activity close to the
seedling. However, the weevils could be out of vision when being close to either of the cameras,
i.e. away from the seedling. Both before and during the entire experimental period the following artificial light regime was used: 18 h light/6 h darkness with visible light intensities of 59 and 0.1 μmol m\(^{-2}\) s\(^{-1}\), respectively (Sky 200 SKP meters; Skye Instruments Ltd., Llandrindod Wells, UK). This light regime was not in phase with the natural light cycle. To avoid that a change in light intensity at the start of the observation sessions influenced the weevils’ behaviour, the sessions were started with a 7 h light phase, followed by the 6 h dark phase, and then an 11 h light phase. The experiment was conducted at room temperature (22 °C).

Each weevil was placed in the cylinder surrounding a seedling a day before the start of each observation session to habituate them to the cylinder. To avoid effects of any feeding scars the seedling was then replaced with a new one after the acclimatization period. Video recording was started when the new seedling was installed and ended 24 h later.

The behaviour of each weevil was observed in two sessions, once with a non-girdled seedling and once with a seedling that had been manually girdled 24 h prior to video recording. The girdling was done by removing a 5 mm ring of outer and inner bark tissues from the stem under the first node. Half of the weevils of each sex were placed in a cylinder surrounding a girdled seedling during the first observation session and the other half in a cylinder surrounding a non-girdled seedling. Cylinders were cleaned with a damp paper towel between observation sessions. Between the observation sessions the weevils were placed for two days in Petri dishes with pieces of Scots pine twigs and a water tube.
The weevils’ behaviours were visually recorded and divided into two mutually exclusive
behaviour groups related to feeding and locomotion as listed in Table 1 (The Observer XT 10,
Noldus Information Technology, Wageningen, Netherlands). Feeding behaviours were observed
continuously in real-time play back speed and the initiation and termination of these behaviours
were recorded with the highest possible resolution allowed by the cameras, 0.04 seconds.
However, other behaviours were observed continuously in 16x real-time play back speed and
short interruptions in these behaviours may therefore have been missed.

Statistical analyses
Each 24-h observation session was split into one-hour periods. Then the total time the weevil
spent in each of the behaviours and the time it spent on the seedling in each hour were
calculated. For comparisons of behaviours in the presence of girdled and non-girdled seedlings
data from the 24-h observation sessions were averaged, whereas for comparisons between sexes
the data were first averaged per individual and subsequently for all individuals together.

The times spent on feeding and in locomotion during the light and dark phases were separately
summed and divided by the total duration of the respective phase. The significance of differences
in these times between light/dark phases with girdled/non-girdled seedlings or male/female
weevils was then tested with 2-way ANOVA (Minitab, Version 16.1.0, Minitab Inc., U.S.A.).

The total time spent on the seedling before and after the first feeding occasion were compared
Computing, Austria) as the data did not always meet normality of distribution (Kolmogorov-
Smirnov, $P < 0.05$) or homogeneity of variance ($F$-test, $P < 0.05$) requirements for parametric tests. The comparison was made separately for observation sessions with non-girdled and girdled seedlings, and differences in the times spent by male and female weevils on different behaviours. In addition, the time until the first feeding occasion was compared between non-girdled/girdled seedlings and male/female weevils using Wilcoxon signed ranks and Mann-Whitney tests, respectively.

To calculate time budgets the proportions of the time during an observation session the weevils spent in locomotion and standing while being on the seedling were calculated. The same was done for the time when weevils were not on the seedling but here a category with “out of vision” was also included. The time they spent standing on the seedling was divided into time when they were and were not feeding. The proportions of times spent on the behaviours between non-girdled/girdled seedlings, and between male/female weevils, were compared using Wilcoxon signed ranks and Mann-Whitney tests, respectively.

In addition, differences in the proportion of times that males and females spent in locomotion or standing when they were not feeding (which met normality of distribution and homogeneity of variance requirements for parametric tests) were assessed using 2-sample $t$-tests.

Results

General diel activity
The locomotion activity of the weevils was higher during the dark phase than during the light phase \((P < 0.001; \text{Figs. 2 a and b, 3 a and b})\), particularly during the first half of the dark phase. Neither sex nor girdling had a significant effect on locomotion \((P > 0.05)\).

The time spent feeding was low from the beginning of the observation sessions to the second half of the dark phase (Fig. 2 c and d, 3 c and d). Feeding time was not influenced by girdled/non-girdled seedlings or light/dark phase \((P > 0.05)\). The interactions between the light phase and girdling or the light phase and weevil sex were neither significant \((P > 0.05)\). Females, however, spent more time feeding than males \((P = 0.04)\).

**Diel activity on the seedling**

Both males and females started feeding a similar time after the beginning of the experiment \((11.3 \pm 0.6 \text{ h and } 7.6 \pm 1.2 \text{ h, respectively; } P = 0.13; N = 12)\). On non-girdled seedlings feeding started later than on girdled seedlings \((11.3 \pm 1.1 \text{ h and } 7.6 \pm 1.2 \text{ h, respectively; } P = 0.02; N = 24)\).

Weevils spent more time on the seedlings during the second half of the dark phase than in the first half (Fig. 2c and d). They also spent significantly less \((P < 0.001)\) time on non-girdled seedlings before \((1.7 \pm 0.6 \text{ min h}^{-1})\) than after \((17.0 \pm 4.3 \text{ min h}^{-1}; \text{Fig. 2c})\) the first feeding occasion, but not on girdled seedlings \((6.5 \pm 4.5 \text{ min h}^{-1}\text{ before, } 11.9 \pm 2.8 \text{ min h}^{-1}\text{ after}; P = 0.052; \text{Fig. 2d})\). Thus, the weevils spent more time on seedlings that had been injured by either manual girdling or weevil feeding.
Female weevils spent more time than males on the seedlings both in total and relative to the time spent feeding (Fig. 3c and d). Males spent more time on the seedlings after the first feeding occurrence (1.0 ± 0.2 min h\(^{-1}\) before, 7.1 ± 1.3 min h\(^{-1}\) after; \(P = 0.03\)) but not females (6.8 ± 4.3 min h\(^{-1}\) before, 21.7 ± 4.0 min h\(^{-1}\) after; \(P = 0.06\)). The time on the seedling that was spent not feeding was not significantly different before (females 6.8 ± 4.3 min h\(^{-1}\); males 1.0 ± 0.2 min h\(^{-1}\)) and after (females 14.9 ± 3.7 min h\(^{-1}\); \(P = 0.31\); males 2.0 ± 0.6; \(P = 0.31\)) the first feeding occurrence for both sexes.

**Time Budget**

Weevils spent on average 6 % (range, 2.1 % to 13.8 %) of the day feeding (Fig. 4). Most of the time they were not on the seedling and during this time they spent a larger proportion of the time standing than in locomotion.

The girdling treatment did not affect the total amount of time allocated to any tested behaviour (\(P > 0.05\); Fig. 4 a and b).

Females spent significantly more of the time on the seedling than males (26 % and 7%, respectively; \(P = 0.01\)). They also spent significantly more time than males in locomotion (4.4 ± 0.4 % and 1.5 ± 0.1 %, respectively; \(P = 0.01\); Fig. 4 d and c) and standing without feeding (14.8 ± 2.0 % and 1.3 ± 0.2 %, respectively; \(P = 0.01\)) on the seedling. However, females did not spend more time than males standing while feeding (7.2 ± 0.5 % and 4.2 ± 0.2 %, respectively; \(P = 0.07\)). When not on the seedling, there was no significant difference between females and males in time spent in locomotion (24.3 ± 1.1 % and 37.8 ± 2.8 %, respectively; \(P = 0.09\)) or in
time spent standing (42.8 ± 2.6 % and 42.5 ± 2.2 %, respectively; \( P = 0.81 \)). However, females
were standing for a higher proportion of the time when they were not feeding than males
(61.9 ± 4.8 % and 45.7 ± 5.2 %, respectively; \( P = 0.049 \)).

The weevils fed predominantly on the stems of the seedlings (96.0 ± 1.2 %, see “food intake”; table 1), but also on needles (4.0 ± 1.2 %).

**Discussion**

This study investigated the diel behaviour pattern and time budget of adult pine weevils with high temporal resolution under laboratory conditions. Feeding on seedlings and locomotion both on and away from seedlings and the time allocated to these behaviours are examined in detail. The effects of girdling seedlings on the weevils’ behaviour are also investigated.

Both locomotion and feeding behaviour show a diel rhythm. Most locomotion occurs during the first half of the dark phase, then locomotion decreases and feeding activity increases during the second part of the dark phase and into the light phase. The increase in locomotion activity in connection with the dark phase is consistent with previous reports on pine weevils and many carabid beetles (Merivee et al., 1998; Pszczolkowski & Dobrowolski, 1999; Thiele & Weber, 1968). Merivee and co-workers (1998) report that the increase of pine weevil locomotion occurs before the onset of the dark phase, which is not clearly seen in the present study. The reduction in locomotion behaviour in the second half of the dark phase is consistent with the pattern described by Pszczolkowski & Dobrowolski (1999). In the field, other factors affect the weevils’ behaviour as well. Locomotion activity is most frequent at dusk and dawn, which coincide with
periods of favourable weather conditions, i.e. moist and moderately warm (Sibul et al., 1999).

Other weevil species, such as the Warren rootcollar weevil, pine root collar weevil, *H. xiaoi*, and apple blossom weevil, also express higher locomotion activity during the night (Cerezke, 1994; Duan et al., 1996; Wen et al., 2004; Wilson, 1968). This study shows that changes in light intensity *per se* can be enough to trigger a diel behaviour pattern, since the present study uses an artificial light and dark cycle, which is not in phase with the natural day-night cycle.

The pine weevils feed mostly during the second half of the dark phase and the beginning of the following light phase, somewhat in accordance with findings by Pohris (1983) that pine weevils feed more during constant darkness than during constant light. In addition, the diel feeding pattern observed in the present study is more strongly expressed in males, possibly because they spend less time feeding than females (present study and Merivee et al., 1998). This may reflect females’ need to spread their feeding behaviour over longer time periods than males as females have to digest larger amounts of food but their digestion times are similar (Nuorteva, 1972).

In contrast to the pine weevil, feeding activity of the apple blossom weevil increases sharply directly after the onset of the dark phase, possibly because its locomotion activity is more evenly distributed during the dark phase (Duan et al., 1996). In the present study, some of the reduction in the pine weevils’ locomotion during the second half of the dark phase may have been due to the onset of feeding behaviour. However, as these behaviours are mutually exclusive it is difficult to determine if the pine weevil’s feeding is concentrated in the second part of the dark phase because locomotion activity predominates in the first part or *vice versa*.
When they are not feeding, males spent less of the time standing than females, in line with previous findings that males have higher locomotion activity than females (Merivee et al., 1998). A possible explanation for this pattern is that the males may search for mates more actively than females, which is common in insects that produce no long-range signals for attracting mates (Brown et al., 1997). Seedlings and other host material have their own attraction potential and males might find females easier in the vicinity of those.

Discrepancies in pine weevil feeding patterns observed in different studies might be partly due to differences in the types of food sources used. Living plants may differ in their responses to weevil damage, e.g. due to their induced defences (Heijari et al., 2005), whereas cut-off twigs, as used by Merivee and co-workers (1998), are already severely damaged. In addition, there are diel patterns in the expression of living plants’ defences, which may as well influence diel patterns of feeding behaviour (Goodspeed et al., 2012). Even minor damage to seedlings may trigger changes in their volatile emissions and make them more attractive to pine weevils (Nordlander, 1991). However, the pine weevil generally responds to these volatiles within a short range from a seedling (Björklund et al., 2003). In the present study, weevils spent more time on both girdled seedlings and non-girdled seedlings after the first feeding occasion than on non-girdled seedlings before the first feeding on them, indicating that they were attracted to damaged seedlings. After the first feeding on non-girdled seedlings their behaviour patterns were similar to those on previously girdled seedlings. Therefore, some of the behavioural patterns we observed on non-girdled seedlings would probably not be observed on cut-off twigs (see Merivee et al., 1998). No differences in time spent feeding on girdled and non-girdled seedlings were observed, maybe due to that the defensive response to the damage had not been completed before the use in the
experiment. Conifers may respond quickly to damage, by e.g. up-regulating the defensive gene expression within a few hours (Ralph et al., 2006) and increase the resin content within 48 hours (Sampedro et al., 2011). However it may take up to a week before responses reach maximum level (Lewinsohn et al., 1991). In the present study, a relatively short period is used between the first and second damage, because this resembles common patterns of weevil attack when seedlings are planted on clear cuts (Björklund et al., 2005; Nordlander, 1991).

Pine weevils only allocate about 6% of their time to feeding behaviour, but this is twice as much as Costa Rican weevils spend on feeding (Wright et al., 1999), whereas apple blossom weevils may spend up to 27% of their time feeding (Duan et al., 1996). The variation between species can be due to differences in their biology, differences in the nutritional value of their host plants or differences in the defence reactions of the host plants (Harrison, 1987).

Most of the feeding observed was on the stem bark, where the pine weevil generally causes damage. A smaller proportion of feeding was observed on needles. Some of the needles were not used as a food resource, but rather the weevils bit them off and then fed on the bark in the vicinity of the removed needle. However, other needles were partly eaten (data not shown), possibly due to differences in nutrition composition or water content between needles and bark (Kaakinen et al., 2004), which may make needles attractive as a supplementary food source.

In this study, a detailed description is presented of diel activity patterns of both male and female pine weevils on both girdled and non-girdled seedlings. The sex of the weevils affects the diel patterns of both feeding and locomotion behaviour as well as the time budget, but the girdling
did not. On average, weevils spent 6 % of their time feeding and 34 % in locomotion and the rest of the time standing. The results of this study, which are the outcome of the interaction between the pine weevil and a conifer seedling, provides basic knowledge for future studies that in the end may enable development of new methods for increasing seedling survival, hence improving the regeneration of managed conifer forests.

Acknowledgements

We thank Henrik Nordenhem and Anders Eriksson for assistance with the practical work and Allan Nordlund for measuring the light conditions. We appreciate the comments of Christer Björkman on the manuscript. This study was financed by the Swedish Foundation for Strategic Research (Parasite Resistant Tree project) and the Swedish forestry sector (The Swedish *Hyllobius* Research Program).


Fedderwitz et al.  Diel behaviour and time budget of pine weevils


<table>
<thead>
<tr>
<th>Behaviour</th>
<th>Definition</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Feeding</td>
<td>Merged group of food intake and biting needles</td>
<td></td>
</tr>
<tr>
<td>Food intake</td>
<td>Manipulation of bark with the mouth parts</td>
<td>Periods of bark removal and ingestion were not distinguished</td>
</tr>
<tr>
<td>Biting needles</td>
<td>Manipulation of needles with the mouth parts</td>
<td>Amount could not be measured</td>
</tr>
<tr>
<td>Locomotion</td>
<td>Any behaviour that transports the weevil from one position to a position more than one weevil length away</td>
<td>Includes short periods of standing (e.g. stop-and-go periods)</td>
</tr>
<tr>
<td>Standing</td>
<td>Remaining within a radius of one weevil length</td>
<td>Includes local movements and feeding</td>
</tr>
<tr>
<td>Out of vision</td>
<td>Not visible on video recording</td>
<td>Weevil may be performing locomotion or standing, but not feeding behaviours</td>
</tr>
</tbody>
</table>
Figure legends

Figure 1: Experimental set-up. A small water tube and a dark coloured shelter for weevils to hide under inside the cylinder are not shown.

Figure 2: Diel behaviour patterns of pine weevil with non-girdled (N = 12) and previously girdled seedlings (N = 12) in total (a, b) and while on the seedlings (c, d). Shaded areas represent the dark phase. Values are means ± one standard error.

Figure 3: Diel behaviour patterns of male (N = 6) and female (N = 6) pine weevil in total (a, b) and while on the seedlings (c, d). Shaded areas represent the dark phase. Values are means ± one standard error.

Figure 4: Time budget of both sexes of pine weevils with access to a non-girdled (a) and a previously girdled (b) seedling (each N = 12) and time budget of male (c) and female (d) weevils (each N = 6) with access to both kinds of seedlings. Values are average percentages of time over the entire 24-hours observation sessions.
Figure 1
Figure 2
Figure 3
Figure 4