Colonization of *Cerambyx dux* Faldermann (Coleoptera: Cerambycidae) in Stone-Fruit Tree Orchards in Fohais Directorate, Jordan*

**Na’im Sa’id Sharaf**

**ABSTRACT**

A field study was conducted in five locations in Fohais Directorate, Jordan, during the period from January 1, 2008 to May 15, 2009 to identify wood borers attacking stone-fruit trees, to determine the economic status of identified species and to investigate the way wood borers colonize host trees. Three wood borers were identified: *Cerambyx dux* Faldermann, *Capnodis tenebrionis* L. and *Synanthedon exitosa* Say. *C. dux* was the most economically important borer as it damages 23.77% of cultivated trees. *C. dux* overwinters as partial-grown larvae, pupae and adults. Adults emerge at the time of blooming of each host and mate. Mated females colonize selected host trees and begin depositing eggs in bark crevices. Selection of preferred trees depends on: tree age, tree bark color and structure, in addition to the chemical defense system of the tree. Plums were more susceptible to colonization by *C. dux* than peaches. Almonds were the least susceptible host. Results were discussed, conclusions were drawn and recommendations for control management of *C. dux* were suggested.

**Keywords**: Stone-fruit trees, Wood borers, *Cerambyx dux*, Fohais Directorate - Jordan.

**INTRODUCTION**

Stone-fruit trees, *Prunus* spp., are cultivated under rainfed conditions in Irbid Governorate (IG) (32°33′N 35°51′E), the northern region of Jordan located about 70 km north of Amman (the capital of Jordan), Fohais Directorate (FD) (32°01′N 35°46′E) located 20 km west of Amman and Ma’daba Governorate (MG) (31°44′N 35°48′E) located 32 km south of Amman. Fohais and Ma’daba represent the middle region of Jordan (Fig. 1).

In these two regions, peaches and nectarines (*Prunus persica*), plums (*Prunus domestica*), almonds (*Prunus amygdalus*), apricots (*Prunus armeniaca*) and green cherries (*Prunus vulgaris*) are heavily infested with wood borers.

The almond flathead rootborer *Capnodis carbonaria* Klug and the peach flathead rootborer *C. tenebrionis* L. (Coleoptera: Buprestidae) are devastating insect pests of cultivated stone-fruit trees in IG (Sharaf, 2008). *C. tenebrionis* alone is a threatening buprestid of stone-fruit trees in MG. *Cerambyx dux* Faldermann (Coleoptera: Cerambycidae) and other wood borers are destructive insect pests of stone-fruit trees in FD (personal observation).

* C. *dux* is the cerambycid borer most frequently encountered in stone-fruit orchards in Jordan (Mahdi, 2000). Worldwide, it is recorded from Bulgaria, Macedonia, Turkey, Greece, Crimea, NW Iran and the Near East (http:// www. cerambyx. uochb. cz/ cerambyxdux. htm). It is a polyphagous insect that attacks and kills fruit trees, ornamental trees and shrubs.
Colonization of Cerambyx dux…


*Figure 1. Main cultivation regions of stone-fruit trees in Jordan.*

*C. dux* develops in living or moribund trees and can therefore be regarded not only an economic pest but also a physiological pest. However, surprisingly little is known about the biology and ecology of this species in Jordan. Therefore, this study was initiated to investigate the economic impact of *C. dux* on stone-fruit trees cultivated in FD through studying its distribution and the way it colonizes infested trees.

**MATERIALS AND METHODS**

Fohais is situated on several freshwater streams that run through the forested area 20 km west of Amman ("Fohais.net". http://www.Fohais.net/2008/main/index.php, 2008). Traditionally, Fohais is considered one of the main stone-fruit producing areas in Jordan. However, during the past three decades many stone-fruit trees were removed because they were heavily infested by wood borers or because of urban development which resulted in the replacement of orchards by human buildings. Consequently, some stone-fruit orchards were substituted by olive groves, others were newly re-established and still other old orchards remained, as they were, intact. The final picture is habitat fragmentation and patchy distribution of stone-fruit plantation in FD. Therefore, FD was divided arbitrarily into five locations (Hommar, Um-Na’ag, Rahwa, Masna’ and Ferdoos) to facilitate coverage of all available orchards. In these locations, all stone-fruit trees cultivated in 17 commercial orchards were inspected for wood borer infestations. Number of infested host trees was recorded and percentage infestation for each host and each location was calculated. Mean percentage infestation of stone-fruit trees in FD was computed.

Commercial orchards in FD varied in their sizes [from few dunums (1 dunum = 0.1 ha) to 1000 dunums], ages (from young orchards of < 5 years old to middle-aged orchards of 5-10 years old to > 10 years old orchards), hosts (almond, plum, peach) and rootstocks (bitter almond, seedling peach rootstock). These variables greatly affect some plant characteristics (time of blooming, bark color and morphology, trunk thickness (diameter), plant defenses), which in turn affect colonization of stone-fruit trees and spacing behavior of wood borers. Plant characteristics are positively correlated with tree age. Therefore, 15 trees were randomly selected, irrespective of their hosts, from orchards harboring wood borer infestations in Hommar and Um-Na’ag locations. Trunk diameter (cm), trunk height above ground level (cm) and horizontal distance (cm) between imaginary vertical lines of each two neighboring infestation holes were measured. Number of infestation holes per tree trunk was also counted.

In large orchards, wood borer infestations varied...
within the same host (e.g., peaches) according to the geographical place of planted trees. The direction of blowing wind might be the reason. Therefore, percentage infestation of trees planted NE was compared with those planted SW.

It was not intended in this study to follow the life cycle of C. dux. However, diapause termination, adult emergence, egg-laying, larva development and pupation were observed in freshly cut infested trees or wood logs, and notes were taken. The abovementioned studies were carried out during the period from January 1, 2008 to May 15, 2009.

RESULTS AND DISCUSSION

Wood Borers: Description

Insects that attack and bore into living trees or freshly cut logs from infested trees are generally referred to as wood borers. The greatest number of wood borers is in the insect orders Lepidoptera (moths) and Coleoptera (beetles). Three wood borer species were found infesting stone-fruit trees in FD. These are the cerambycid beetle, C. dux Faldermann, the buprestid beetle, C. tenebrionis L. and the sesiid moth S. exitosa Say.

C. dux belongs to the longhorned beetles or roundheaded borers (Coleoptera: Cerambycidae). The common name of longhorned beetles comes from their long filamentous antennae, which is one of the distinguishing characteristics of the family Cerambycidae (http://www.rottler.com/pest-library/pdf/longhorned_beetles.pdf); often extending up to or past the abdomen. The name roundheaded borer is given to the larva because of its swollen, rounded thoracic region directly behind the head and its habit of boring through wood as it feeds (http://www.rottler.com/pest-library/pdf/longhorned_beetles.pdf). C. dux has sexual dimorphism between males and females, with males having much longer antennae (Fig. 2). Adults of C. dux are dark brown in color, with a body length of 2.5 – 4.5 cm and unusually shaped eyes (like kidney beans).

C. tenebrionis belongs to the flatheaded borers (Coleoptera: Buprestidae). The adults are dull black in color, medium in size (body length 1.8 - 3.0 cm, width 0.7 - 1.2 cm) and usually somewhat flattened. Pronotum is white with a black irregular central spot bordered from each side by two lateral spots. Elytra are black in color, ridged or roughened, bearing small white spots (Fig. 3) (Abu Jbara, 2005). The larvae lack eyes and legs, are distinctly segmented and have very small heads and greatly enlarged and usually flattened thoraxes, the latter feature having given rise to the name, "flatheaded borers" (http://insects.ucr.edu/ebeling/ebel5-2.html#roundheaded%20borers).

Figure 2. Sexual dimorphism in Cerambyx dux.

Figure 3. Capnodis tenebrionis: adult (dorsal view).
S. exitosa belongs to the peach tree borers or crown borers ((Lepidoptera: Sesiidae). Female peach tree borer moths have a superficial resemblance to wasps. Female is about 2.5 cm in length, has a steel-blue body with an orange band on the fourth and sometimes on the fifth abdominal segment. The forewings are blue and the hindwings are clear with a black margin. Males are slightly smaller than females and lack the orange band on the abdomen (Fig. 4) (http://www.coopext.colostate.edu/TRA/PLANTS/index.html#http://www.coopext.colostate.edu/TRA/PLANTS/peachtreeborer.html).

The round- and flatheaded wood borers are usually easily distinguished by their large size, especially in the later larval instars. Cerambycid larvae are cylindrical, fleshy dirty white, legless and reach about 10 cm at maturity. They have darkened, strong, well-developed mandibles. Buprestid larvae lack eyes and legs, are distinctly segmented and flattened, have very small heads but powerful mandibles and reach about 7 cm at maturity. Cerambycid larvae taper less abruptly from front to rear than buprestid larvae do. Also, the cerambycids do not possess an inverted "V" on the large first thoracic segment as buprestid larvae do (Fig. 5).

![Figure 4. Male and female Synanthedon exitosa.](image)

![Figure 5. Characteristics distinguishing larvae of round- and flatheaded wood borers.](image)
Larvae of peach tree borer are white with brown heads and reach about 4 cm at maturity (Fig. 6).

Pupae found in cells hollowed out of the shredded (cerambycids) (see Fig. 12: cross-section of larvae tunnels) or powdered (buprestids) frass are distinguished by their resemblance to the adults, with cerambycids possessing long, coiled antennae (Fig. 7).

Damage Symptoms

The three wood borers infesting stone-fruit trees in FD share the same feeding guild. They start their infestations in the bark of tree stems. Under these circumstances, interspecific competition is expected. Competition can be alleviated or prevented by niche partitioning in time and space. Peachtree borer, *S. exitosa*, is a specialized xylophage infesting the lowest part (from soil surface up to 15cm height) of peach tree stems in late January and early February. Roundheaded borer, *C. dux*, is a polyphagous wood borer, which infests thick branches and the upper part of the stems of peaches as well as plums and almonds in late March and early April. Stone-fruit trees infested with *C. dux* will not be infested by the flatheaded borer, *C. tenebrionis*. Both beetle species tend to partition stone-fruit trees on the basis of beetle size because each species shows the highest survival in wood that is thick enough to accommodate growing larvae (see Table 2).

Stone-fruit trees in FD display a variety of damage symptoms that can be easily used to distinguish infestation incurred by each of the three wood borers. Larvae of wood borers induce wounds in the bark of infested stone-fruit trees. Trees respond to this injury through their oleoresin system which constitutes a physical-chemical defense against invasion by wood borers. Oleoresin system “pitches out” adult wood borer insects by trapping them in the resin and forcing them out of the tree. The oleoresin, or pitch, flowing from severed resin ducts hinders the penetration of the bark (Schowalter, 2006).

Terpenes are primary resin components of pitch,
produced by many plants to seal wounds. Pitch flow in response to injury by insect feeding can physically push the insect away, deter further feeding, kill the insect or do all three (Nebeker et. al., 1993). Pitch, consisting of relatively low-molecular weight terpenoids, is a generalized wound repair mechanism of many stone-fruit trees that seals wounds, infuses the wound with constitutive terpenoids and physically prevents the penetration of the bark by insects.

In peaches, the response to crown wounding by larval feeding of *S. exitosa* results in a proliferation of cells of clear white liquid resin that turns upon oxidation in the air into glazed black color. Pitch flow surrounds wound lesion and about half of the crown area beneath it (Fig. 8). Pitch flow is more obvious in the case of *C. dux* invasion. It flows from the wounded lesion of the trunk downwards to the crown area in a thickened stream strand. When exposed to air, it becomes hardened and brown in color (Fig. 9).

**Figure 8. Pitch flow of *S. exitosa*.**  
**Figure 9. Pitch flow of *C. dux*.**

Stone-fruit trees do not respond to wounding of larval feeding of *C. tenebrionis* in a pitch flow of oleoresin in the crown area. Instead, gum-mosis, or gum-flow, is the result of bark injury. Visible first is the exudation of gum crystals at the point of infestation. Crystals slowly enlarge with the collapse of the inner bark tissue, reaching a small size of small clear amber shining gum ball. In older infestations, the bark becomes torn. The gum turns black from alternate wetting and drying and from the presence of decaying organisms (Fig. 10).

**Figure 10. Gum-mosis due to bark injury by *C. tenebrionis*.**
In addition to niche partitioning and variable characteristics of injury, wood borers infesting stone-fruit trees in FD display a variety of habits. Larvae of *C. dux* expel large quantities of well visible sawdust on the ground below the infested part of the trunk which can serve as a hallmark to locate attacked trees (Fig. 11). Larval feeding habits typically result in frass-filled tunnels within the sapwood and heartwood of the host plant, terminating in a pupal chamber (averaging size: $3 \times 1.5$ cm) (Fig. 7), wherein the metamorphosis from last-instar larva to pupa to adult takes place. Tunnels change in shape and dimensions with the development of larvae in the wood. At the beginning of boring, circular holes in the size of pin heads filled with tight fine frass can be found on the outer surface of newly infested bark trees. With the progress of boring in the sapwood and heartwood, tunnels of variable sizes (ranging from $>1.0$-10.0 cm in length and $>0.5$-3.5 cm in width) resembling the sizes of the different developmental larval instars tend to be oval in cross-section and have the frass tightly or loosely packed into them. Frass texture is very coarse and almost excelsior like. Exit holes are oval or oblong in cross-section, with lengths of 2.5 – 2.7 cm and a width of 1 cm (Fig. 12). Roundheaded borers attack unseasoned wood. They do not re-infest seasoned wood (http://www.rottler.com/pest-library/pdf/longhorned_beetles.pdf). The tunnels made by cerambycid larvae in host trees are roughly circular in cross-section and can be more than an inch (2.5 cm) wide (http://news.ucanr.org/newsstorymain.cf?story=1127).

![Figure 11. Large quantity of sawdust expelled by larva of *C. dux*.](image1)

![Figure 12. Larvae tunnels and adult exit holes of *C. dux*.](image2)
Colonization of *Cerambyx dux*...  

Adults of *C. tenebrionis* feed on the leaves and cortex of twigs and young branches of stone-fruit trees, occasionally causing heavy damage. Larvae feed upon the inner portion of the bark and cambium of the roots and trunk and to a less extent, on the wood (Fig. 13a). Masses of clear gum exude from the injured areas. These are usually amber colored (see Fig. 10) and appear higher up on the trunk. Damage is often noticed only when a part of the tree ceases to develop or shows signs of drying up or defoliation. Death follows larval attack on young trees. Mature trees are seriously weakened by the larvae (Rivnay, 1945; Avidov and Harpaz, 1969; Garcia Del Pino and Morton, 2004, http://www.inra.fr/internet/Produits/HYPPZ/RAVAGEUR/capten.htm).

Larvae form large, sinuous galleries in the main roots (Fig. 13b), full of sawdust, terminating in a pupal chamber, wherein metamorphosis from last-instar larva to pupa to adult takes place. Galleries made by the larvae of *C. tenebrionis* tend to have approximately the same shape as their thoraxes - about 3 times broader than high. In this respect, the tunnels frequently can be distinguished from the more nearly rounded (oval) tunnels of the roundheaded borer, *C. dux*.

**Figure 13.** Damage caused by larvae of *C. tenebrionis*. 13a, Larvae feed upon the inner portion of the bark and cambium of the roots; 13b, Larval gallery in main root.

The first sign of injury inflicted by *S. exitosa* is a mass of gum at the base of the trunk. The gum may be mixed with brownish frass and sawdust, which give it a dark color (see Fig. 8) (http://www.organicgardening.com/feature/0,7518,sl-5-16-148-2-1X2X3-4,00.html). Larvae can cause extensive damage by burrowing into the sapwood of the tree, usually at or below soil line. Damage can be a general decline in tree health, expressed in all or part of the tree, wilting of portions of a tree or tree death (Hammon, B., Peach Tree Borer: Life History and Management Options for Western Colorado. Retrieved from: http://www.coopext.colostate.edu/TRA/PLANTS/peachtreeborer.html).

**Distribution**

Stone-fruit trees cultivated in five locations in FD were inspected for wood borer infestations based on damage symptoms. Results are presented in Table 1. 4642 trees of different ages of peaches, plums and almonds cultivated in 17 orchards located in Um-Na’ag, Hommar, Ferdoos, Masna’ and Rahwa were inspected for infestation with the roundheaded borer, *C. dux*, the flatheaded borer, *C. tenebrionis* and the peachtree borer, *S. exitosa*. 607 trees were infested with *C. dux*, 5 trees were infested with *C. tenebrionis* and 3 trees were infested with *S. exitosa*. Percentage infestation caused by...
the three wood borers was 13.08, 0.07 and 0.04 for *C. dux*, *C. tenebrionis* and *S. exitosa*, respectively. Consequently, *C. dux* is considered to be the most important wood borer in FD. Cerambycids are distributed worldwide, wherever their host plants are found (Monné and Bezark, 2008: Retrieved from http://www.cerambycids.com/default.asp). *C. dux* is the cerambycid borer most frequently encountered in stone-fruit plantations (http://www.barkbeetles.org/spb/Coleopte.htm).

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### Table 1. Infestation percentage of stone-fruit trees by *Cerambyx dux* in five locations in Fohais Directorate.

<table>
<thead>
<tr>
<th>Location</th>
<th>No. of inspected orchards</th>
<th>Host</th>
<th>Total of inspected trees</th>
<th>No. of infested trees</th>
<th>Infestation (%)</th>
<th>Tree age (years)¹</th>
</tr>
</thead>
<tbody>
<tr>
<td>Um-Na’ag</td>
<td>3</td>
<td>Peach</td>
<td>345</td>
<td>202</td>
<td>58.55</td>
<td>&gt; 10</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Plum</td>
<td>319</td>
<td>94</td>
<td>29.47</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Almond</td>
<td>11</td>
<td>0</td>
<td>0.00</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td></td>
<td>675</td>
<td>296</td>
<td>43.85</td>
<td></td>
</tr>
<tr>
<td>Hommar</td>
<td>3</td>
<td>Peach</td>
<td>1560</td>
<td>256</td>
<td>16.41</td>
<td>&gt; 10</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Plum</td>
<td>60</td>
<td>20</td>
<td>33.33</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Almond</td>
<td>25</td>
<td>5</td>
<td>20.00</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td></td>
<td>1645</td>
<td>281</td>
<td>17.08</td>
<td></td>
</tr>
<tr>
<td>Ferdoos</td>
<td>3</td>
<td>Peach</td>
<td>234</td>
<td>30</td>
<td>12.82</td>
<td>5-10</td>
</tr>
<tr>
<td>Masna³)</td>
<td>7</td>
<td>Peach</td>
<td>1230</td>
<td>0</td>
<td>0.00</td>
<td>&lt;5</td>
</tr>
<tr>
<td>Rahwa</td>
<td>1</td>
<td>Peach</td>
<td>858</td>
<td>0</td>
<td>0.00</td>
<td>&lt;5</td>
</tr>
<tr>
<td>Grand Total</td>
<td>17</td>
<td></td>
<td>4642</td>
<td>607</td>
<td>13.08</td>
<td></td>
</tr>
</tbody>
</table>

1. Stone-fruit orchards were classified into three groups; newly established orchards with trees of <5 years old, middle-aged orchards with trees of 5-10 years old and old orchards with trees of >10 years old.
2. Only three peach trees were infested with the peach tree borer, *Synanthedon exitosa*.
3. Only five peach trees were infested with the flatheaded borer, *Capnodis tenebrionis*.

Infestation of stone-fruit trees varied within the five studied locations. Stone-fruit trees were not infested with *C. dux* in Masna’ and Rahwa locations. Infestation percentage was 12.82 in Ferdoos location, 17.08 in Hommar location and reached 43.85 in Um-Na’ag location (Table 1). Masna’ and Rahwa orchards are newly established orchards having young stone-fruit trees of less than 5 years old. Ferdoos orchards are re-established plantations having stone-fruit trees aging between 5 and 10 years. Hommar and Um-Na’ag orchards are old plantations having stone-fruit trees of more than 10 years old.

*C. dux* selects stone-fruit trees that are thick enough to accommodate growing larvae. These trees are usually more than 6 cm in diameter or more than 5 years old (Table 2). Frequency of attack by *C. dux* measured as number of infestation holes per tree trunk increased linearly with increased growth of stone-fruit trees. It
Colonization of *Cerambyx dux* increased with trunk diameter but not with trunk length. Number of infestation holes was almost zero (mean 0.25) in young trees of less than 5 years old with a trunk diameter of less than 6 cm. Mean infestation holes increased to 2.9 \([(2.33 + 3.50)/2]\) with the increase in trunk diameter from 6 to 10 cm in middle-aged trees of 5-10 years old. Mean infestation continued to increase and reached 5.75 holes per trunk in more than 10 years old trees having trunks of more than 10 cm in diameter (Table 2). Hammon reported that peach tree borers usually damage trees that are more than 5 cm in diameter. He also mentioned that trees with old damage are more susceptible to repeated attacks (Hammon, B., Peach Tree Borer: Life History and Management Options for Western Colorado. Retrieved from: http://www.coopext.colostate.edu/TRA/PLANTS/index.html# http://www.coopext.colostate.edu/TRA/PLANTS/peachtreeborer.html).

Spacing behavior of *C. dux* was measured as the horizontal distance in cm between two imaginary vertical lines of each two neighboring entry holes. Surprisingly, this distance was always 8 cm (Table 2). This means that *C. dux* has a regular (uniform) distribution pattern as its individuals space themselves at regular intervals within the habitat. This distribution pattern is typical of species that contest resource use, especially territorial species. Such spacing reduces the competition for resources (Schowalter, 2006). *C. dux* also shows a clumped (aggregated) distribution pattern on severely damaged trees (see Fig. 12: cross-section of larvae tunnels). Aggregated, cooperative feeding on plants, such as by sawflies and bark beetles, can remove plant tissues or kill the plant before induced defenses become effective (McCullough and Wagner, 1993).

Table 2. Frequency of attack and spacing behavior of *Cerambyx dux* as affected by age and growth of stone-fruit trees.

<table>
<thead>
<tr>
<th>Tree age (years)</th>
<th>No. of tree measured</th>
<th>Trunk circumference (cm)</th>
<th>Trunk diameter (cm)</th>
<th>Trunk length (cm)</th>
<th>No. of infestation holes / trunk</th>
<th>Distance between each two neighboring entry holes (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;5 years old</td>
<td>1</td>
<td>26</td>
<td>4.14</td>
<td>42</td>
<td>0</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>32</td>
<td>5.10</td>
<td>50</td>
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<td>-</td>
</tr>
<tr>
<td></td>
<td>3</td>
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<td>5.25</td>
<td>43</td>
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</tr>
<tr>
<td></td>
<td>4</td>
<td>37</td>
<td>5.89</td>
<td>57</td>
<td>1</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Mean</td>
<td></td>
<td></td>
<td></td>
<td>0.25</td>
<td></td>
</tr>
<tr>
<td>5-10 years old</td>
<td>5</td>
<td>40</td>
<td>6.37</td>
<td>18</td>
<td>2</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>42</td>
<td>6.69</td>
<td>23</td>
<td>0</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>7</td>
<td>45</td>
<td>7.17</td>
<td>42</td>
<td>5</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>Mean</td>
<td></td>
<td></td>
<td></td>
<td>2.33</td>
<td></td>
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<tr>
<td></td>
<td>8</td>
<td>51</td>
<td>8.12</td>
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<td></td>
<td>9</td>
<td>53</td>
<td>8.44</td>
<td>55</td>
<td>2</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>55</td>
<td>8.76</td>
<td>47</td>
<td>3</td>
<td>8</td>
</tr>
</tbody>
</table>
Table 3. Susceptibility of stone-fruit host trees to infestation by Cerambyx dux in FD.

<table>
<thead>
<tr>
<th>Host</th>
<th>No. of inspected trees</th>
<th>No. of infested trees</th>
<th>Infestation (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peach</td>
<td>2139</td>
<td>488</td>
<td>22.81</td>
</tr>
<tr>
<td>Plum</td>
<td>379</td>
<td>114</td>
<td>30.08</td>
</tr>
<tr>
<td>Almond</td>
<td>36</td>
<td>5</td>
<td>13.89</td>
</tr>
<tr>
<td>Total</td>
<td>2554</td>
<td>607</td>
<td>23.77</td>
</tr>
</tbody>
</table>

C. dux uses acoustic signals to maintain minimum distances between individuals boring through the wood of colonized trees. Stridulation contributes to optimal spacing and resource exploitation by colonizing wood borers. Subsequently, excavating adults and larvae respond to the sounds of approaching excavators by mining in a different direction, thus preventing intersection of tunnels (see Fig. 12: cross-section of larvae tunnels). Many orthopterans and some beetles advertise their territories by stridulating (Rudinsky and Ryker, 1976). Stridulation was clearly heard as an adult male was approached in an attempt to pull it out of its resting tunnel (see Fig. 15).

Host Plants

Susceptibility of host trees (peach, plum and almond), measured as percentage infestation, is presented in Table 3. Plums were the most susceptible host, followed by peaches. Almonds were the least susceptible host. Percentage infestation of plum, peach and almond trees was 30.08, 22.81 and 13.89, respectively.

Susceptibility of stone-fruit host trees might be affected by a variety of variable physical and chemical plant characteristics. Almond is the first host that blooms early in the spring (late February and early March), followed by plums (late March) and then peaches (late April). Almond flowers are white, whereas those of plums are rosy and those of peaches are pink (Fig. 14). White color deters wood borers from landing on their host trees (http://www.attra.org/attra-pub/peach.html). In addition to flower color, time of blooming is important.
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Blooming is initiated earlier in plums than in peaches. Consequently, plums will succumb earlier and over longer period of time to infestation than peaches. Aromatic volatile compounds produced by plum flowers might also aid in the attraction of *C. dux* adults which results in higher susceptibility of plum trees (see notes on plum flower in Fig. 14).

Bark texture and color might have great impact on host susceptibility. Peach bark is greenish-gray with lenticels, often has thorns or spines. Plum bark is dark-brown in color and smooth in texture. Almond bark is pale-brown and rugged (Fig. 14). Again, adults of *C. dux*, like other wood borers, are attracted to dark-colored silhouettes of tree boles (Goyer *et al.*, 2004; Strom *et al.*, 1999); in this case to plums more than to peaches or almonds. Spines and hairs can inhibit attachment or penetration by small insects or interfere with ingestion by larger organisms (Schowalter, 2006). This might be another factor that contributes to the higher susceptibility of plums as compared to peaches.

As with many other members of the rose family, peach seeds contain cyanogenetic glycosides, including amygdalin. These substances are capable of decomposing into a sugar molecule and hydrogen cyanide gas. Peach and almond belong to the same subgenus *Amygdalus*. Their seeds contain this toxic substance, but with varying concentrations. Almonds are more toxic than peaches. Plums belong to another subgenus, *Prunus* and are less toxic than peaches (http://en.wikipedia.org/wiki/Almond, http://en.wikipedia.org/wiki/Peach, http://en.wikipedia.org/wiki/Plum). The three hosts contain the same toxic substances but with varying concentrations. This might have a great effect on host susceptibility, with plums being the most susceptible.

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**Figure 14. Plant characteristics of stone-fruit host trees.**

- **Peach Flower**: The flowers are produced in early spring before the leaves, they are solitary or paired, 2.5–3 cm in diameter, pink with five petals. Bark is greenish-gray, often with thorns or spines.
- **Peach Bark**: The flowers grouped 1–5 together on short stems. When it flowers in the early spring, a plum tree will be covered in blossom. Flowers are rosy in color with adorable scent. Bark is dark-brown and smooth.
- **Plum Flower**: The flowers are white, 3–5 cm in diameter with five petals, produced singly or in pairs before the leaves in early spring. Bark is pale-brown and rugged.
- **Almond Bark**: The flowers are produced in early spring before the leaves, they are solitary or paired, 2.5–3 cm in diameter, pink with five petals. Bark is greenish-gray, often with thorns or spines.
Susceptibility of stone-fruit host trees varied between infested locations as well as within the same location. For example, percentage infestation of peach trees was 12.82 in Ferdoos. It was 16.41 in Hommar and 58.55 in Um-Na’ag (Table 1). This variation in host susceptibility between the three locations might be due to the previously discussed age factor. However, in the same location, such as Hommar, 71% of peach trees planted SW were infested, as compared to 5% infestation of peach trees planted NE. Topographic relief creates gradients in solar exposure and soil drainage, as well as in temperature and moisture (Schowalter, 2006). SW-directed plantations provide more suitable (warmer and drier) local habitats for *C. dux* than those directed NE. *C. dux* is also known as diurnal, strong flier cerambycid.

Migrating adults of *C. dux* are displaced downwind into areas where converging air masses rise. In this case, in Hommar, displacement occurs with the wind blowing from NE to SW. Migration occurs seasonally and displaces large numbers of cerambycids downwind from overwintering sites to areas with more suitable habitat conditions (Matthews and Matthews, 1978).

**Colonization**

*C. dux* overwinters as partial-grown larvae, pupae or adults. Adults have been found in early January, 2008 in freshly cut wood logs resting in tunnels side by side with the grown larvae. This was repeatedly seen in February, March and April 2009 (Fig. 15). Insects in woody habitats may be relatively protected from large changes in air temperature and relative humidity.

In nature, diapause of individual insects of *C. dux* may terminate at different times during the winter. Yet, growth does not resume throughout the population until the development threshold has been reached. Other factors, such as the availability of water and food, are also important. The local population is consequently synchronized in growth by environmental conditions during late winter and spring. Adults of *C. dux* resume their activities in late winter, excavate exit holes and feed on nectar of herbaceous plants (Fig. 16) or blossoms of host trees. Males emerge first, wait for females to emerge and then mate. Mated females lay eggs in February on almonds, in March on plums and in April on peaches. Egg-laying is synchronized with the time of blooming of the three host trees. At this time, newly fresh expelled sawdust (see Fig.11) was visible on the soil around the base of trunks of previously attacked trees, indicating either reactivation of overwintering...
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boring larvae or adults leaving infested trees through their exit holes (see Fig. 12).

Newly emerged adults of C. dux search for new hosts in their vicinity or reinfest old ones expanding their distribution on a spatial scale. Adults may also migrate, sometimes wind-aided, if resources are depleted and relocate suitable hosts in their new habitats. Migration occurred downwind from NE to SW in Abu-Daieh / Hommar orchard (Fig. 16). In this orchard, severely damaged trees were cut, burnt and turned to charcoal, with heavy smoke emitted from them. Directed dispersal provides the highest probability of successful colonization and is observed in larger, stronger fliers capable of orienting toward suitable resources. Many wood-boring insects, such as wood wasps and beetles, are attracted to sources of smoke, infrared radiation or volatile tree chemicals emitted from burnt or injured trees over distances of up to several kilometers (Evans, 1966; Gara et al., 1984; Mitchell and Martin, 1980; Raffa et al., 1993; Wickman, 1964). Attraction to suitable hosts is often significantly enhanced by mixing with pheromones emitted by early colonists. Visual or acoustic cues also may aid orientation (Goyer et al., 2004; Strom et al., 1999).

After landing on a suitable host tree, females of C. dux deposit their eggs either singly or in small patches consisting of 10 eggs arranged in two vertical rows each having 5 eggs. Eggs are deposited in bark crevices or in wounded lesions of the upper trunk, glued to the outer surface of the bark and to each other. After hatching of larvae, empty eggcups were visible. Eggcups will be blown by the wind as the glue material dry or fall to the ground if they were touched. Female cerambycid beetles lay their eggs in wood or bark crevices during spring, summer or early autumn. Eggs are laid singly or in small groups (http://www.rottler.com/pest-library/pdf/longhorned_beetles.pdf). Because the eggs are laid over a long period of time, the larvae vary greatly in size (http://www.attra.org/attra-pub/peach.html).

Hatched larvae move downwards, search for suitable entry point (see Fig. 12) and start boring into the bark. As they grow, they bore deeper into the sapwood and heartwood and move down the trunk as cold weather approaches. Because adults of C. dux infest new hosts as well as previously attacked ones and because the eggs are laid over a long period of time, the actual number of larval instars and the development time of larval stage are difficult to establish precisely under field conditions. Despite these constraints, number of larval instars can be estimated by tracing their tunnels in freshly cut wood logs from infested trees of the same host (e.g. peach). Tunnels tend to have approximately the same shape and size of their larval instars. A second approach could be also used to determine the number of larval instars. Larvae shed off their head capsules when they molt from one larval instar to another during their development. Head capsules can be extracted from tunnels by the emersion of infested wood parts in water. Floating head capsules can be collected and measured. Different sizes (dimensions) of head capsules correspond to different larval instars. Following both methods, at least 5 larval
instars could be recorded for *C. dux* (Fig.17). Cerambycids spend most of their life time in the larval stage, being prolonged by a low nutritional value of the wood and a decrease in moisture (http://www.rottler.com/pest-library/pdf/longhorned_beetles.pdf). Pupation takes place in a cell (see Fig. 7) near the wood surface. The time of adult emergence depends on environmental conditions in late February and during spring. Adults feed, disperse, mate and reproduce within a short life span (Monné and Bezark, 2008; Retrieved from http://www.cerambycids.com/default.asp) and the cycle is repeated again.

![Graph showing the estimated number of Cerambycid dux larval instars based on the widest part (cm) of cross-sections of larval tunnels](image)

**Figure 17.** Estimated number of *Cerambycid dux* larval instars based on the widest part (cm) of cross-sections of larval tunnels (1st instar larva is not shown in the Figure).

**CONCLUSIONS AND RECOMMENDATIONS**

The following conclusions and recommendations could be drawn from the current study:

1. Three wood borers attack stone-fruit trees cultivated in FD. These are: the roundheaded borer, *C. dux*, the flatheaded borer, *C. tenebrionis* and the peach tree borer, *S. exitosa*. Of these, *C. dux* is the most economic important borer as it infests 13.08 % of cultivated trees at the Directorate level and 23.77 % in infested locations. These percentages are expected to increase with the progress in trees’ age in infested and noninfested locations.

2. Damage symptoms characteristic of *C. dux* can be easily distinguished from the damage symptoms inflicted by the other two borers. Larvae of *C. dux* expel large quantities of well visible sawdust which can serve as a hallmark to locate attacked trees. Other symptoms could be used such as gum-mosis which describes mainly infestations incurred by *C. tenebrionis* and the black glancing “pitch flow” at lower trunk which characterizes the infestation by peachtree borer.

3. Stone-fruit trees infested by *C. dux* will not be infested by *C. tenebrionis* and *vice versa*. Both borers are strong competitors and can’t co-exist together. Also, young trees of less than 5 years old are not infested by *C. dux* because they do not have trunks thick enough to
accommodate the large grown cerambycid larvae. Growers should not be worried about borer infestation in young orchards.

4. Almonds are less susceptible to infestation by *C. dux* than plums and peaches. Almonds are raised on better almond rootstocks which contain a strong chemical defense system, whereas plums and peaches are raised on seedling peach rootstocks which are characterized by a relatively weak chemical defense system. Therefore, highly infested trees should be removed from orchards and replaced by stone-fruit trees raised on better almond rootstocks.

5. Females of *C. dux* are attracted to black-colored tree boles, or to trees that have previously been damaged by borers, or to which some mechanical injury has occurred. Therefore, it is important to avoid damaging the bark when cultivating around trees and to apply a white latex paint, painted or sprayed on the trunks which provides a physical barrier, inhibiting newly hatched larvae from entering the trunk. The paint also fills the cracks in the bark, the preferred site for oviposition and larval feeding.

6. It is easy to detect a tree that is infested with wood borers, since large amounts of sawdust or gum are expelled from the damaged trees. The grower can use this expel to locate a larva and then kill it by using a flexible wire to probe it out of the trunk. This method of control is feasible for small plots but probably not practical in a commercial orchard.

7. Larvae, in general, are vulnerable to insecticide sprays only from the time they hatch until they burrow beneath the bark. For effective control, a larva must be exposed to a toxic amount of insecticide before it burrows under the bark. Given the extended egg laying period of *C. dux*, multiple sprays may be necessary. Residual effectiveness of insecticides varies considerably with the particular compound used and environmental conditions. Growers must be aware of the characteristics and limitations of the insecticide used to time, sprays so that a continuous insecticidal barrier to larva entrance to the bark is in place.

8. Seasonal histories of *C. dux* vary considerably. Timing of initial sprays will vary by several weeks over the diverse habitats and environmental conditions present in FD. Timing is based on adult emergence, which is determined by pheromone captures. Therefore, further study on pheromone identification should be initiated. Their trapping efficiency under field conditions should also be evaluated. Other cultural and biological control measures are to be studied, so that an integrated management program for controlling wood borers in stone-fruit orchards in FD can be implemented.

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