

Activity rhythm of the banana weevil, *Cosmopolites sordidus* Germar (Coleoptera: Curculionidae)

Abstract

Laboratory and field investigations on the activity rhythm of the banana weevil, *Cosmopolites sordidus* Germar indicated a nocturnal lifestyle for this pest. This behaviour persisted even under constant dark (DD) condition, during free-running trials. This proved an endogenously controlled, true circadian rhythm for the pest. Activity generally commenced sharply with the start of scotophase (6pm) reaching peaks at about 9pm and maintaining that level till about 4am, and gradually declined with the start of photophase (6am). Light was a major deterrent to the pest, as constant light (LL) condition completely suppressed activity. Temperature and light intensity correlated negatively with weevil activity ($r=-0.726$, $P<0.01$; $r=-0.690$, $P<0.01$ respectively), but positively with relative humidity ($r=0.821$, $P<0.001$). These findings provide baseline information on the behaviour of the pest, and will help to guide the timing of future laboratory and field experiments on the pest.

Keywords: Activity rhythm, diel behaviour, light regime, scotophase, endogenous, free-running rhythm

Introduction:

The banana weevil, *Cosmopolites sordidus* Germar (Coleoptera: Curculionidae) is recognized globally as the major insect pest of bananas and plantains. It causes considerable production losses yearly, all over the world (Ostmark, 1974; Tinzaara *et al.*, 2011). The pest attacks all species of *Musa* and no cultivar has total resistance to it; certain cultivars are however, now known to be more susceptible to the borer than others (Viswanath, 1981; Mesquita *et al.*, 1984; Gold *et al.*, 2001).

Currently, no single control strategy guarantees effective control (Gold *et al.*, 2001). As a result, integrated approaches comprising farm hygiene, careful varietal selections, pseudostem and pheromone trappings, properly selected insecticides and so on are often adopted in controlling this pest.

Knowledge of various facets of pest biology, ecology and behaviour is absolutely essential for development of novel control (Bottrell, 1979; Kumar, 1984). Activity rhythm profiling or chrono-

biological studies on pests can greatly enhance our knowledge of pest life, biology and their temporal organizations (Lazzari and Insausti, 2008). This can ultimately aid in their control, especially when appropriate measures are adopted at critical moments in their diel or seasonal cycles. Periods of ecdysis or hatching for instance, would be times of high susceptibility for pests, since body cuticle is most permeable and thus, most vulnerable at such moments (Lazzari and Insausti, 2008).

Understanding the peak times of activity for a pest can also adequately instruct researchers on the need for correct timing of studies (especially laboratory-based semio-chemical studies); and can also guide the timing of field interventions, for effective control of pests. This study was therefore undertaken with a view to unraveling the diel behaviour of the banana weevil, and to possibly help open-up the opportunity for better control options against this pest.

Materials and methods:

(a) Preliminary laboratory studies on activity rhythm

A preliminary study on the activity of the banana weevil was performed in the laboratory over 13 days, with a view to gaining a rough idea about the behaviour of the insect in 24-hours. Into each of two wooden cages (each measuring 80 x 80 x 50cm) were introduced 200 weevils (100 males and 100 females). The base of each cage was filled with soil to a depth of 10cm and two pairs of pseudostems (each piece approx. 20 cm long and 8cm high) were placed on the soil to act as food and shelter for the weevils. The split pseudostems were placed approx 20cm away from the centre of the cages; each pseudostem was placed directly opposite the other.

The soil in each cage was kept moist with water on the first day of the experiment and the weevils introduced into the cage were allowed the entire day to settle down before commencement of data collections. Records on weevil activity namely, movement, feeding and mating were made for 10 minutes, at hourly intervals (over a 24-hr period), beginning from the second day till the end of the experiment (i.e. 12 days later). Activity here was defined as any visible actions of the pest occurring within the cage, but not underneath the split pseudostems. The experiments were conducted under 12L:12D light regime in the laboratory; with temperature and relative humidity ranging between 25 $\pm$ 2°C and 80 $\pm$ 5% respectively.

Torch-lights covered with red-light filters (Kodak Wratten No 70) and transmitting only wavelengths greater than 640nm were used during observation periods at night. Such dim light made observations in the dark possible, with no obvious disturbance to the insects (adapted from Budenberg *et al.*, 1993; Uzakah *et al.*, 2015).

66 (b) Free-running rhythm in the laboratory

67 After gaining some insights into the daily activity of the insect under a 12L:12D condition (as stated
68 above), a closer look at the diel behaviour of the pest was undertaken over a shorter time-frame of
69 12 hours (i.e. 6L:6D) daily, using nine smaller cages of size 38 x 38 x 38cm each (Plate 1). This was
70 done because the preliminary study revealed a somewhat 'mirror-image' of the activity of the weevil
71 during periods "12noon–12midnight" and "12midnight–12noon". So for this stage of experiments, a
72 shorter daily observation period (12noon – 12 midnight) was chosen, to allow for more painstaking
73 observations. Also, for ease of monitoring the activity of this pest, the experiments were done in a
74 laboratory room with altered light regime, with the scotophase (dark phase) starting at 2pm. 12pm
75 and 12midnight thus corresponded to 8am and 8pm respectively in this room. Weevils used in this
76 study were left in this light regime for a week to acclimatize before they were used.

77 Hourly records on weevil activity were kept as the experiments progressed. For the first two days of
78 the experiments, all the nine cages were kept in 12 hours of light and 12 hours of dark (LD condition)
79 in the room. On the third day of the experiment, three cages were transferred to a room with
80 constant light (LL condition), and another three to a room with constant darkness (DD condition);
81 while the last three remained in the LD condition. All transfers were done at exactly 5.30pm (i.e. the
82 usual "lights-off" time). All rooms were identical and maintained at same conditions of $25 \pm 2^{\circ}\text{C}$ and
83 $80 \pm 5\%$ relative humidity. The experiments lasted for six days. The results or observations made
84 under the different conditions (LL, DD and LD) were then compared at the end of the experiments.



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96 **Plate 1: The wooden cages used in the free-running rhythm studies of the banana weevil, in the**
97 **laboratory**

98 **(c) Field investigations at Mbita Point Station, S. Kenya**

99 Field investigations on the activity rhythm of the weevil were undertaken on a 3-acre plot at Mbita
100 Point Field Station, South Nyanza, Kenya. The field is located along the shores of Lake Victoria on
101 latitudes 0°25 and 0°30S, longitudes 34°11 and 34°20E, altitude 1200m, annual temperature range
102 24-31°C, relative humidity 40-60% and yearly average rainfall of 900mm during 2 rainy seasons
103 (March-July and September-December, respectively). The vegetation is a savannah/semi-arid type,
104 with clay-cotton, black and moderately basic soil type.

105 Fifty (50) banana traps were randomly set across the farm. At regular intervals of 2h in each 24h
106 cycle (for 9 days), these traps were inspected for weevil activities (i.e. for number of weevils
107 trapped, number found feeding, mating or moving on/around the traps). Trap catches were not
108 released back into the field, but were taken to the laboratory for other studies. Records of daily
109 weather parameters (mean temperature, mean relative humidity and mean rainfall) were also kept
110 for possible correlations between environmental parameters and weevil activity.

111 **Results:**

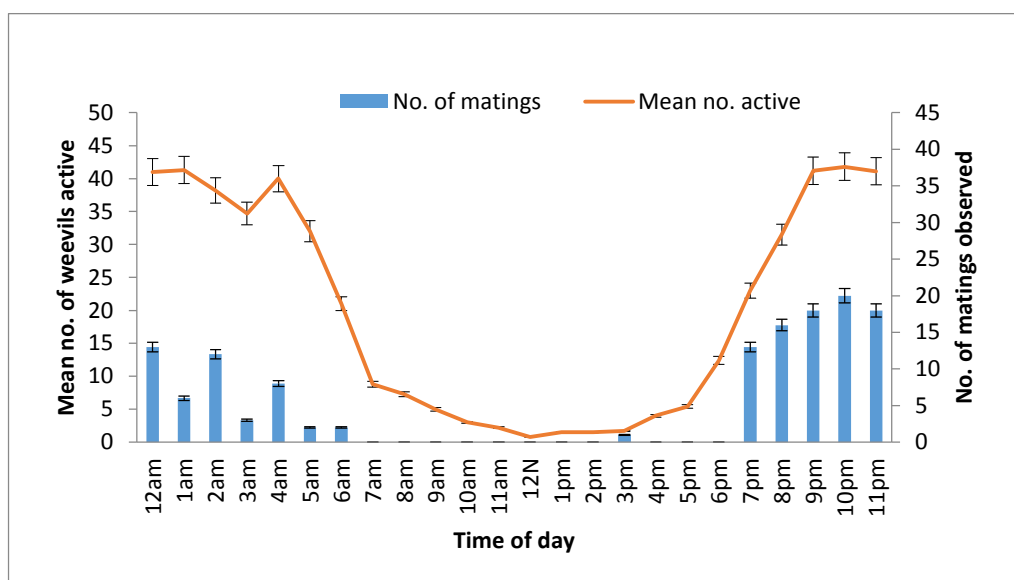
112 **(a): Preliminary laboratory investigations on the activity rhythm**

113 The preliminary laboratory studies conducted on the activity rhythm showed that there was a
114 mirror-image of activity for the periods of 12 noon to 12 midnight and 12 midnight to 12 noon (Fig.
115 1).

116 The weevils were most active from 6pm to 6am every day. Activity rose sharply from 6pm reaching
117 the peak at about 9pm and remained at that level till 4am when it started to fall gradually. It
118 decreased sharply after 6am with sunrise, reaching its lowest level at 12 noon. Photophase in the
119 lab, which occurred between 7am–5pm, seemed to inhibit weevil activity, while scotophase (6pm–
120 dawn) was associated with high activity.

121 Mating frequency also followed the same general pattern as shown in Fig. 1. It was rarely observed
122 during the photophase, being virtually restricted to the scotophase alone. Thus only 0.8% record of
123 mating was made during photophase (7am–5pm) in this study compared with 99.2% during
124 scotophase (6pm-6am) (n=132).

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127 **Fig. 1: The diel activity of the banana weevil *C. sordidus* under laboratory conditions**
128 **as influenced by time of day**

129 **(b): Free-running rhythm in the laboratory**

130 Fig. 2 presents the activity trend of the weevil during the free-running rhythm (FRR) trials in a 12-h
131 cycle, for the period under investigation. The weevils displayed a nocturnal habit, as they generally
132 commenced activity at or soon after dark or lights-off at 5.30pm. Fig. 2A shows the trend for the
133 first 2 days under 12L:12D condition (i.e. preparatory to the free-running trials); while Fig. 2B-E
134 reveals the trend during FRR.

135 Day 3 of the experiments (which is actually Day 1 of FRR) (Fig. 2B) showed that weevil activity
136 followed same pattern as the previous (Fig. 2A); rising soon after 5.30pm, except for the LL condition
137 where activity was clearly suppressed. The trend was exactly the same on day 2 of FRR (i.e. the day 4
138 of the experiment) as more insects became active soon after 5.30pm (Fig. 2C). This observation is
139 also true for even the cages that were now in constant darkness (DD). It did not continue
140 indefinitely, but was restricted to the usual times only (similar to those in LD condition). Activity in LL
141 however, was again completely suppressed.

142 However, on day 3 of FRR, activity under DD condition shifted slightly, commencing after 6pm but
143 not under LD conditions, as activity continued as usual starting soon after 5.30pm (Fig. 2D). Activity
144 under LL condition was virtually non-existent on this day having been completely suppressed by the
145 constant light. It remained like this for the entire duration of the study. Mating, throughout the

146 study, was also restricted to the periods of high activity only (i.e. with the onset of scotophase); it
147 was virtually absent in the photophase. Of the 65 total matings recorded, only 1.5% occurred under
148 light conditions; the rest 98.5% occurred in DD.

149 The natural periodicity (r) of this rhythm could not be calculated, because observations were made
150 for only 12 hours each day and not for 24 hours.

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Mean number of active weevils observed

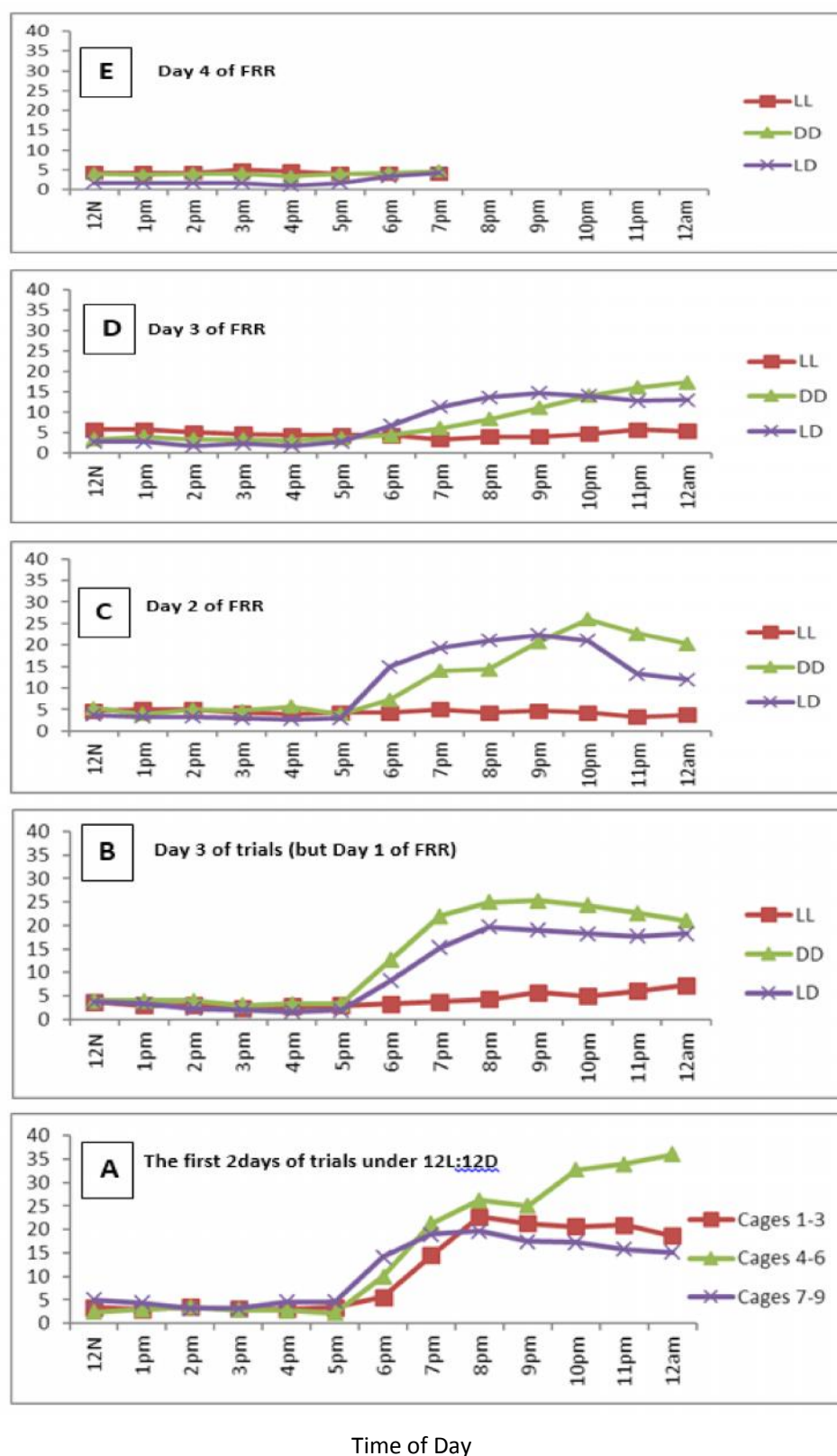


Fig. 2: The free-running rhythm of the banana weevil, *C. sordidus* in the laboratory

(After the first 2 days, cages 1-3 were transferred to LL; cages 4-6 to DD, while cages 7-9 remained in LD)

(c): Field Investigations at Mbita Point Station, S. Kenya

The field investigations revealed highly significant weevil activity during the night (i.e. for periods of 6pm-6am) than during the day (6am-6pm) ($P < 0.0001$); confirming the nocturnal nature of this pest (Table 1 and Fig. 3). All three weather parameters (mean temperature, mean relative humidity and mean light intensity) had significant effects on weevil activity. While mean r.h. was positively correlated with the mean number of weevils caught ($r = 0.821$, $P < 0.001$), mean temperature and mean light intensity correlated negatively with mean weevil activity ($r = -0.726$, $P < 0.01$; and $r = -0.690$, $P < 0.01$, respectively) (Table 2 and Fig. 3)

Table 1: Comparison of weevil populations caught at Day and Night times at Mbita Point Field Station, S. Kenya

Time	No. of observation	No. caught	Mean	Variance
Day	42	49	1.167 ^b	2.045
Night	42	279	6.643 ^a	21.650

Means with same letters are not significantly different at 5% level, Student's t-test

Table 2: Correlation matrix between environmental parameters and weevil activity

		Mean No. Active.	Temp (°C)	Rel Hum. (%)	Light Intensity (X100 lux)
Mean No. Active	Pearson Correlation	1	-.726**	.821**	-.690*
	Sig. (2-tailed)		.008	.001	.013
	N	12	12	12	12
Temp (°C)	Pearson Correlation	-.726**	1	-.962**	.916**
	Sig. (2-tailed)	.008		.000	.000
	N	12	12	12	12
Rel Hum (%)	Pearson Correlation	.821**	-.962**	1	-.888**
	Sig. (2-tailed)	.001	.000		.000
	N	12	12	12	12
Light Intensity (X100 lux)	Pearson Correlation	-.690*	.916**	-.888**	1
	Sig. (2-tailed)	.013	.000	.000	
	N	12	12	12	12

** . Correlation is significant at the 0.01 level (2-tailed).

* . Correlation is significant at the 0.05 level (2-tailed).

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209 **Fig.3: The fluctuations in no. of banana weevils, *C. sordidus* caught at different times of the day**

210 **in relation to environmental conditions at Mbita Point Field Station, S. Kenya**

211

212 **Discussions**

213 The laboratory studies on the activity rhythm of the banana weevils have clearly revealed that these
214 insects restrict their activities to certain times of the diel cycle. Activity generally commenced at or
215 soon after the onset of scotophase and continued more or less uniformly throughout the dark
216 period, but virtually came to a standstill during the photophase.

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218 The endogenous nature of this behaviour was clearly revealed when the weevils were transferred
219 from LD cycle to DD, as the rhythm persisted under these “free-running” trials. According to Aschoff
220 (1960), when an organism is transferred from LD to DD or LL, under constant conditions of
221 temperature and other possible influences, an endogenous oscillation controlling the rhythmic
222 activity free-runs reveals its natural periodicity (τ). In such a state, τ often deviated slightly from 24 h,
223 so that onset or peak activity appeared either earlier or later by a few minutes each day.
224 Unfortunately, in this study, the progressive daily shifts could not be determined as the experiment
225 (FRR) only lasted for 3 days. The natural periodicity (τ) also could not be calculated because the
226 period of observation was 12hrs daily (for easy and sustained monitoring) and not 24hrs. However,
227 the persistence of the rhythm in the DD and the slight shift from the usual time for onset of activity
228 on day 2 of FRR, is a clear evidence of the endogenous nature of this rhythm in *C. sordidus*. This
229 assertion is supported by Beck (1980), who noted that if an insect became active each day beginning
230 about an hour after sunset and remained active for several hours before finally becoming relatively
231 quiescent until the same time the next day, and this daily pattern of activity and quiescence
232 continued even under experimental conditions, then, amongst other conclusions that could be
233 drawn, is the fact that the activity is not simply evoked by the light-off stimulus of sunset. It is rather
234 a manifestation of an endogenous circadian rhythm which can be entrained by environmental
235 photoperiod. The observations made in this study, clearly show that the activity rhythm of *C.*
236 *sordidus* is in nature, maintained in synchrony with photoperiod, by means of small daily
237 adjustments in response to sunrise or sunset. This is very true because when the photoperiod
238 stimuli, which usually entrained the rhythm was artificially removed, under laboratory conditions of
239 DD, the rhythm free-run exhibited a gradual shift from the normal time for onset of activity.

Constantinou's (1979) work also revealed that locomotory activity in three adult triatomid bugs (*Rhodnius prolixus*, *Triatoma infestans* and *Panstrongylus megistus*) followed a strictly nocturnal trend, with pronounced peaks at onset of darkness. He showed that in constant dark (DD) and constant light (LL) conditions, the activity rhythm of these bugs, free-ran to reveal their true circadian nature.

The findings made in this study on the diel activity of *C. sordidus*, is in agreement with those of Cuille (1950), who also observed a marked diel rhythm for the pest, that persisted in continuous darkness (DD). His finding that activity occurred between 18 hours and 0600 hours, followed by a virtually motionless period of about 12 hours (i.e. 6am – 6pm) was also confirmed in this study. However, some minimal activity was observed also during the day (i.e. between 6am – 6pm) in this study. This finding disagreed with Delattre's (1980) claim that no regular activity existed under DD for the banana weevil. This study clearly showed that the diel rhythm of the pest persisted even under DD. Continuous light (LL) completely suppressed activity.

The results from the diel activity and from the free-running studies of *C. sordidus* show that laboratory experimentations with these insects (e.g. pheromonal bioassays, mating trials etc) could be conducted between ca. 2 hours after scotophase and ca. 2 – 3 hours before photophase as this period generally ensured fairly high and virtually uniform activity amongst the weevil population.

The field observations on the pest were similar to the laboratory findings as the pest still clearly exhibited a well marked nocturnal rhythm. Significantly high activity was recorded during the night than during the day. Light, as already observed in the laboratory studies was a major factor associated with the diel behaviour of this pest under field conditions. Similar observation was made by Poinar and Gyrisco (1960) on the alfalfa weevil. The minimal activity which was observed during the day in the field particularly under banana traps and plant debris, had also been reported by Delattre (1980).

The peak period of activity in the field occurred between 10pm and midnight, though some fairly high and reasonably significant activity was also recorded by 8 pm, and between 2 – 4am. The results from this study suggest that for accurate estimates of adult populations (or level of infestation) of *C. sordidus* in fields, surveys should be embarked upon in the evenings or at night, as was also recommended by Poinar and Gyrisco (1960) for the alfalfa weevils. Samplings at 12 midnight might not be feasible but the period between 7 and 10pm, which also guarantees significant numbers (catches), would be less problematic.

this study has provided important baseline information to guide future experiments. it should also equally eliminate time wastages on fresh activity rhythm profiling for the weevils. the findings made in this study will most importantly, help with correct timing of sensitive experiments e.g. pheromonal and mating related investigations; and will also have possible implications for timing of interventions (control options/strategies) in the field.

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