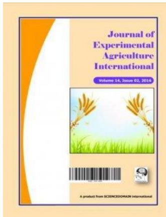

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Activity Rhythm of the Banana Weevil, *Cosmopolites sordidus* Germar (*Coleoptera*: *Curculionidae*)

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Author's contribution

The sole author designed, analyzed, interpreted and prepared the manuscript.

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ABSTRACT

Laboratory and field investigations in Kenya, East Africa, on the activity rhythm of the banana weevil, *Cosmopolites sordidus* Germar indicated a nocturnal lifestyle for this pest. This behavior 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 (6 pm) reaching peak 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 correlated positively with relative humidity ($r=0.821$, $P<0.001$). These findings provide baseline information on the behavior of the pest, and will help to guide timing of future laboratory and field experiments on the pest.

Keywords: Diel behavior; light regime; scotophase; endogenous; free-running rhythm.

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1. INTRODUCTION

The banana weevil, *Cosmopolites sordidus*Germar (Coleoptera: Curculionidae) is recognized globally as the major insect pest of bananas (*Musa* spp) and plantains (*M. paradisiaca*). It causes considerable production losses yearly all over the world [1,2]. The pest attacks all species of *Musa* and no cultivar has total resistance to it. Certain cultivars are, however, more susceptible to the borer than others [3,4,5].

Currently, no single control strategy guarantees effective control [5]. As a result, integrated approaches comprising farm hygiene, careful varietal selections, pseudostem and pheromone trappings, properly selected insecticides are often adopted in controlling this pest.

Knowledge of various facets of pest biology, ecology and behaviour are absolutely essential for the development of novel control [6, 7] Activity rhythm profiling or chrono-biological studies on pests can greatly enhance our knowledge of pest life, biology and temporal organizations [8]. This can ultimately aid in their control, especially when appropriate measures are adopted at critical moments in pest diel or seasonal cycles. Periods of ecdysis, for instance, would be times of high susceptibility to pests, since body cuticle is most permeable and thus, most vulnerable at such moments [8].

The laboratory studies on the activity rhythm of *C. sordidus* have clearly revealed that this pest restricts its activities to certain periods of the diel cycle. This activity generally commenced soon after the onset of scotophase and continued uniformly throughout the dark period. But it virtually came to a standstill during the photophase.

Understanding the peak times of activity of 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 pests control. This study was therefore undertaken with a view to unraveling the diel behavior of the banana weevil, and to possibly help open-up the opportunity for better control options against this pest.

2. MATERIALS AND METHODS

2.1 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 behavior of the insect in 24-hrs. Into each of two wooden cages (each measuring 80 x 80 x 50 cm) 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 sliced banana pseudostems (each piece approximately 20 cm long and 8 cm high) were placed on the soil to act as food and shelter for the weevils. The split was placed approximately 20cm away from the center of the cage and 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 the commencement of data collection. 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); this activity 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±2°C and 80±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 [9,10]).

2.2 Free-running Rhythm in the Laboratory

After gaining some insights into the daily activity of the insect under a 12L:12D condition (as stated above), a closer look at the diel behavior of the pest was undertaken over a shorter time-frame of 12 hrs (i.e. 6L:6D) daily, using nine smaller cages of size 38 cm^3each (Plate 1). This was done because the preliminary study revealed a somewhat ‘mirror-image’ of the activity of the weevil during periods “12 noon–12 midnight” and “12midnight–12noon”. For this stage of experiment, a shorter daily observation period (12 noon – 12 midnight) was chosen, to allow for more painstaking observations. Also, for ease of monitoring the activity of this pest, the experiment was carried out in a laboratory room with altered light regimes, with the scotophase (dark phase) starting at 2 pm. 12 pm and 12midnight thus corresponded to 8am and 8pm respectively in the room. Weevils used in this study were left in this light regime for a week to acclimatize before they were used. Hourly records on weevil activity were recorded as the experiment progressed. For the first two days of the experiment, all the nine cages were kept in 12 hrs of light and 12 hrs of dark (LD condition) in the room. On the third day of the experiment, three cages were transferred to a room with constant light (LL condition), and another three to a room with constant darkness (DD condition); while the last three remained in the LD condition. All transfers were done at exactly 5.30pm (i.e. the usual “lights-off” time). All rooms were identical and maintained under same conditions of 25±2°C and 80±5% relative humidity. The experiment lasted for six days. The results or observations made under the different conditions (LL, DD and LD) were then compared at the end of the experiments.

2.3 Field Investigations at Mbita Point Station, South Kenya

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

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

Plate 1. The wooden cages used in the free-running rhythm studies of the banana weevil in the laboratory

3. RESULTS

3.1 Preliminary Laboratory Investigations on the Activity Rhythm

The preliminary laboratory studies conducted on the activity rhythm showed that there was a mirror-image of activity for the periods of 12 noon to 12 midnight and 12 midnight to 12 noon (Fig. 1). The weevils were most active from 6pm to 6am every day. Activity rose sharply from 6pm reaching the peak at about 9 pm and remained at that level till 4 am when it starts to fall gradually. It decreased sharply after 6 am with sunrise, reaching its lowest level at 12 noon. Photophase in the lab, which occurred between 7am–5pm, seemed to inhibit weevil activity, while scotophase (6 pm–dawn) was associated with high weevil activity.

Mating frequency also followed the same pattern as shown in Fig.1. The process was rarely observed during photophase, but restricted to scotophase period alone. The result showed only 0.8% records of mating was made during photophase (7 am–5pm) compared with 99.2% during scotophase (6pm-6am) (n=132).

3.2 Free-running Rhythm in the Laboratory

The result in Fig. 2 shows the activity trend of the weevil during the free-running rhythm (FRR) trial in a 12-hrs cycle. The weevils displayed a nocturnal habit, as they generally commenced activity at or soon after dark or lights-off at 5.30 pm. Fig. 2A shows the trend for the first 2 days under 12L:12D condition (i.e. preparatory to the free-running trials); while Fig. 2B-E reveals the trend during FRR. Day 3 of the experiment (which is actually Day 1 of FRR) (Fig. 2B) showed that weevil activity followed same pattern as the previous (Fig. 2A); rising soon after 5.30pm, except for the LL condition where activity was clearly suppressed. The trend was exactly the same on day2 of FRR (i.e. the day 4 of the experiment) as more insects became active soon after 5.30 pm (Fig. 2C). This observation is also true for even the cages that were in constant darkness (DD). Activity did not continue indefinitely but was restricted to the usual times only (similar to those in LD condition). Activity in LL, however, was again completely suppressed. On day3 of FRR, activity under DD condition shifted slightly, commencing after 6pm but not under LD conditions, as activity continued starting soon after 5.30 pm (Fig. 2D). Activity under LL condition was virtually non-existent on this day having been completely suppressed by the constant light. It remained like this for the entire duration of the study. Mating observed in this study was restricted to the periods of high activity only (i.e. with the onset of scotophase); it was virtually absent in the photophase. A total of 65 matings were recorded, only 1.5% occurred under light condition and the rest (98.5%) occurred in DD.

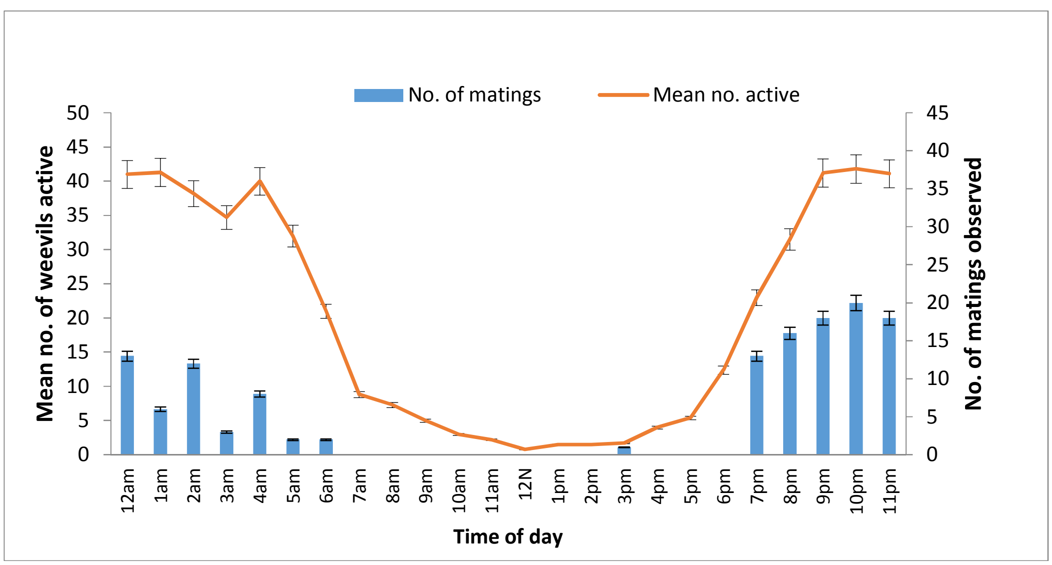

Fig. 1. The diel activity of the banana weevil *C. sordidus* under laboratory conditions as influenced by time of day

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

3.3 Field Investigations at Mbita Point Station, South Kenya

The field investigations revealed highly significant weevil activity during the night (6pm-6 am) than during the day (6 am-6 pm) (P<0.0001) and thus confirmed the nocturnal nature of this pest (Table 1 and Fig. 3). All three weather parameter means (temperature, relative humidity (RH) and light intensity) had significant effects on weevil activity. The result furthermore showed that RH was positively correlated with the number of weevils caught (r=0.821, P < 0.001), temperature and light intensity correlated negatively with weevil activity (r=-0.726, P< 0.01; and r=-0.690, P<0.01, respectively). The result is presented in Table 2 and Fig. 3.

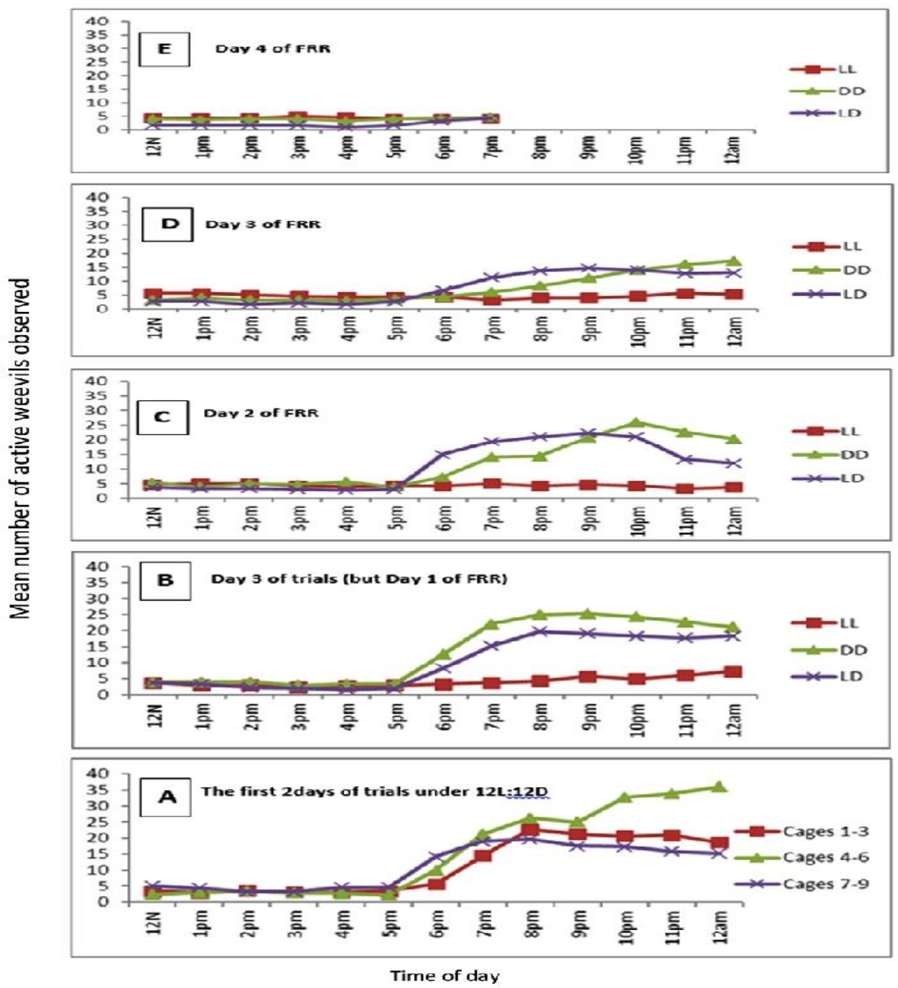

Fig. 2: The free-running rhythm of the banana weevil, *C. sordidus* in the laboratory

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

Table 1. Comparison of weevil populations caught at day and night times at mbita point field station, South Kenya

Time	No. of observation	No. caught	Mean	Variance
Day	42	49	1.167[b]	2.045
	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 (ºC)	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 (ºC)	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).*

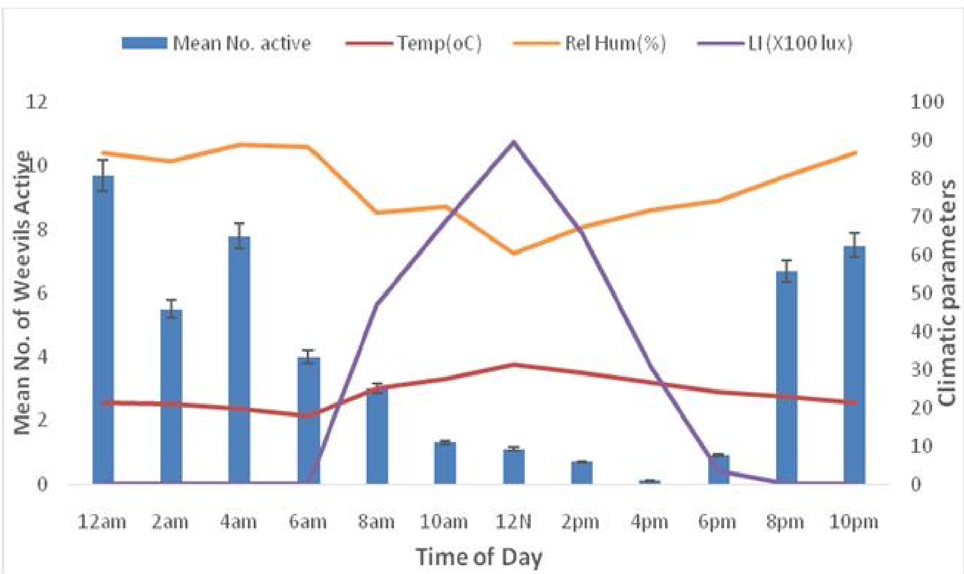

Fig.3: Fluctuations in number of banana weevils, *C. sordidus* caught at different times of the day in relation to environmental conditions at Mbita Point Field Station, South Kenya

4. DISCUSSION

The endogenous nature of this behavior was clearly revealed when the weevils were transferred from LD cycle to DD, as the rhythm persisted under these "free-running" trials. According to [11], when an organism is transferred from LD to DD or LL under constant conditions of temperature and other possible influences, an endogenous oscillation controlling the rhythmic activity free-runs reveals its natural periodicity (r). In such a state, r often deviated slightly from 24 h, so that onset or peak activity appeared either earlier or later by a few minutes each day. However, the persistence of the rhythm in the DD and the slight shift from the usual time for onset of activity on day 2 of FRR, is a clear evidence of the endogenous nature of this rhythm in *C. sordidus.* This assertion is supported by [12], who noted that if an insect became active each day beginning about an hour after sunset and remained active for several hours before finally becoming relatively quiescent until the same time the next day, and this daily pattern of activity and quiescence continued even under experimental conditions, then, amongst other conclusions that could be drawn, is the fact that the activity is not simply evoked by the light-off stimulus of sunset. It is rather a manifestation of an endogenous circadian rhythm which can be entrained by environmental photoperiod. The observations made in this study, clearly show that the activity rhythm of *C. sordidus* is in nature, maintained in synchrony with photoperiod, by means of small daily adjustments in response to sunrise or sunset. This is very true because when the photoperiod stimuli which usually entrained the rhythm was artificially removed under laboratory conditions of DD, the rhythm free-run exhibited a gradual shift from the normal time for onset of activity. [13] 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; same author 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 obtained in this study on the diel activity of *C. sordidus* is in agreement with those of [14]. The Author observed a marked diel rhythm for the pest that persisted in continuous darkness (DD) between 18 hrs and 0600 hrs; followed by a virtually motionless period of about 12 hrs (i.e. 6am – 6pm). Similar observations were also made in this study, though some minimal activity was recorded in this circumstance during the day (i.e. between 6am – 6pm). This finding disagreed with [15], who claimed 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 trials with these insects (e.g. pheromonal bioassays and mating) could be conducted approximately 2 hrs after scotophase and 2–3 hrs before photophase. This period generally ensured fairly high and virtually uniform activity amongst the weevil populations.

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 behavior of this pest under field conditions. Similar observation was made by [16], 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 [15].

The peak period of activity in the field occurred between 10 pm and midnight, though some fairly high and reasonably significant activity was also recorded at 8 pm, and between 2–4 am. The results from this study suggest that for accurate estimates of weevil populations (or level of infestation) of *C. sordidus* in fields, surveys should be embarked upon in the evenings or at night. This was also similar to the recommendation made by [16] 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 wastage on fresh activity rhythm profiling for the weevils. The findings obtained in this study will most importantly help in the correct timing of sensitive experiments, e.g. pheromonal and mating related investigations. It will also have possible implications for timing of interventions (control options/strategies) in the field.

5. CONCLUSION

The studies on the activity rhythm of *C. sordidus* have revealed an endogenously controlled, true circadian (nocturnal) rhythm for the pest. This nocturnal cycle generally peaked at about 9 pm and persisted till about 4 am, when it gradually declined with the onset of photophase. The pest's activity also generally correlated positively with relative humidity but negatively with temperature and light intensity. The findings recorded provide baseline information on the pest's ecology and population dynamics; and will help to guide timing of future laboratory and field experiments. Most importantly, it shall guide timing of interventions or control options against the pest.

COMPETING INTERESTS

Author has declared that no competing interests exist.

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