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Penetration of *Phoenix canariensis* drupes by the date stone beetle *Coccotrypes dactyliperda* (Coleoptera, Curculionidae, Scolytinae)

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Abstract. Date stone beetles (*Coccotrypes dactyliperda* Fabricius, 1801) tunnel into palm seeds to establish brood galleries with their larvae consuming the seed's albumen. Prior work examining the location of the initial penetration holes in de-fleshed seeds had shown a preference for the dorsal groove. This paper presents the data of a follow-up experiment that examined the preferences for penetration holes on complete drupes. Using 100 repeats of a single freshly harvested drupe offered to a single beetle, the study found an overwhelming preference for the beetles to penetrate the drupe at the pedicel scar, with all other sectors significantly less utilised. The implications of this are discussed.

Keywords: Spermatophagy, feeding behavior, locomotion, activity patterns, palmae, insect biology

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Introduction

The date stone beetle, *Coccotrypes dactyliperda* (Fabricius, 1801), is a cryptic spermatophagus beetle (Coleoptera: Curculionidae: Scolytinae: Dryocoetini), which attacks the green drupes of the date palm (*Phoenix dactylifera* L.) (Hussein, 1990), causing the bulk of these to abscise one to two days later (Blumberg, 2008) resulting in production losses between 20 and 40% (Hussein, 1990; Blumberg & Greenberg, 1976). The species also predates the seeds of fallen dates, often after the pericarp has been consumed by other animals, such as rodents. *C. dactyliperda* also attack other palms, in particular the Canary Island date palm (*Phoenix canariensis* Chabaud, 1882) (Boraei, Khodeir & El-Hawary, 1994; Spennemann, 2018, 2019a).

C. dactyliperda spends almost its entire life cycle inside the seeds of palms. Only during dispersal do females emerge for a short period of time, seeking out new seeds (Spennemann, 2022a, 2022b). While the species is well studied for its haplodiploid reproductive behavior (Abd-Allah & Tadros, 1994; Berg *et al.*, 2003; Boraei, 1994; Boraei *et al.*, 1994; Holzman *et al.*, 2009; Jordal *et al.*, 2002; Kadosh, 2019; Roonwal, 1971; Sitkov-Shar on *et al.*, 2017), it is of little surprise that, given that the activities of *C. dactyliperda* are primarily cryptic, there are only very few published observations that examine the behaviour of the species (Spennemann, 2019b, 2020a, 2020b, 2021a, 2022b).

The tunnelling behaviour on defleshed seeds was examined by Adolf Herfs (1948, 1950), who primarily commented on factors such as hardness of seeds and traction, and by the author who examined aspects of gnawing action and traction when penetrating the seeds of *Phoenix canariensis* (Spennemann, 2021a) as well as the location of penetration holes on seeds with breeding galleries (Spennemann, 2020c, 2021b). That research demonstrated a clear preference for penetration in the dorsal groove of the seed, which was attributed to the beetle obtaining greater traction at that location compared to the smooth sides. Given that most attacks occur in the drupe stage, it was deemed desirable to assess experimentally whether *C. dactyliperda* would preference selected areas of the drupe for penetration.

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Materials and methods

Origin of the beetles

The *Coccotrypes dactyliperda* beetles used in this experiment were drawn from a population at the PC2 laboratory of the Peter Till Laboratories, Faculty of Science, Charles Sturt University (Albury, Australia) bred for use in a multi-factorial experiment, assessing food choices and emergence times (Spennemann, 2018, 2020d). The original beetle population stemmed from *Phoenix canariensis* seeds collected at Alma Park, NSW, Australia (Spennemann *et al.*, 2018).

Set-up

The experiment used 100 replicates of the following experimental set up. A single *Coccotrypes dactyliperda* specimen drawn from the breeding population was placed in a plastic 50 ml sample vial together with a *Phoenix canariensis* drupe freshly harvested at the *Khalal* (orange) ripening stage from a palm in suburban Albury (NSW, Australia). The vials were observed at 24-hour intervals to assess the state of penetration. After 48 hours all drupes had been penetrated to some degree. Penetration of the seed was evident with the ejection of frass (Fig. 2).

Recording the location of penetration

To record the positioning of the penetration hole, the curved front (ventral) and flattish back (dorsal) of a seed were divided into nine sectors each (Fig. 1) (following Spennemann, 2021b). The positioning of the penetration hole was recorded. The drupe was divided into six sectors, based on a proximal (A–C) and a distal (D-F) half. Sectors C and D are bounded by the central line and by the turning point towards the apex. Sectors B and E are the shoulder sections, while sectors A and F are the pedicel scar and the apex respectively.

Controls

A series of theoretical controls were created. For the drupe penetration, one control assumed an even representation of penetrations per sector; one was based on the relative surface area of the sectors; and one was based on random numbers. The latter were generated using the RAND function in MS Excel. One hundred sets of random numbers were generated for the drupe sectors, (for numbers between 1 and 6). The controls for the seeds one control assumed an even representation of penetrations per sector while the second was based again based on 100 sets of random numbers (numbers between 1 and 18 corresponding with sectors a–i for the ventral side and sectors k–s for the dorsal side of the seed; Fig. 1).

Statistics

The significance assessment of observed differences in frequencies and percentages used the Chi-squared test with n-1 correction of the MEDCALC comparison of proportions calculator (Campbell, 2007; MedCalc Software, 2018; Richardson, 2011).

Results

The results show an overwhelming preference for the beetles to penetrate the drupe at the pedicel scar (sector A, 60%, Table 1). The shoulder sections at the proximal and distal end of the drupe, as well as the apex, were the least favoured. Sector A is significantly more favoured than any of the other sectors ($p < 0.001$) and significantly more favoured than predicted by any of the three controls (Table 1).

Table 1. Frequency (in %) of the location of the initial penetration hole in *Phoenix canariensis* drupes. Significance in the difference between the observed frequency and controls. Significance coding: * p≤0.05; ** p≤0.01; *** p≤0.001. See Fig. 1 for location codes.

		theoretical distribution			significance of difference		
		(controls)					
sector	actual distribution	even	area	random	actual *vs.* even	actual *vs.* area	actual *vs.* random
A	60	16.67	2.62	10	***	***	***
B	5	16.67	13.75	13	**	*	*
C	14	16.67	33.63	19		**	
D	13	16.67	35.95	15		**	
E	6	16.67	12.60	23	*		**
F	2	16.67	1.45	20	**		***
n	100	100	100	100			

When considering the penetration of the seed, the overwhelming majority of penetrations occurred on the dorsal side in sector l (51%, Table 2), which, together with its ventral pair sector b, is located at the proximal end of the seed. Sector l is significantly more favoured than any of the other sectors ($p < 0.001$) and also significantly more favoured than predicted by the two controls (Table 2).With the exception of sector q (which is significantly underrepresented) none of the other sectors differ significantly from a nominally uniform (even) distribution. Some statistical differences occur when considering a random distribution, with sectors c, d, g, h, i, k q and s being underrepresented in the actual observed sample.

Table 2. Frequency (in %) of the location of the initial penetration hole in Phoenix canariensis seeds. Significance in the difference between the observed frequency and controls. Significance coding: * p≤0.05; ** p≤0.01; *** p≤0.001. Fig. 1 for location codes.

Side	sector	actual distribution	theoretical distribution (controls) even	theoretical distribution (controls) random	significance of difference actual *vs.* even	significance of difference actual *vs.* random
ventral	a	1	5.56	6		
	b	7	5.56	5		
	c	1	5.56	7		*
	d	4	5.56	8		*
	e	4	5.56	6		
	f	3	5.56	1		
	g	1	5.56	7		*
	h	1	5.56	9		**
	i	2	5.56	7		*
dorsal	k	2	5.56	8		*
	l	51	5.56	1	***	***
	m	4	5.56	1		
	n	5	5.56	3		
	o	1	5.56	6		
	p	6	5.56	6		
	q	0	5.56	8	*	**
	r	3	5.56	3		
	s	4	5.56	8		*
n		100	100	100		

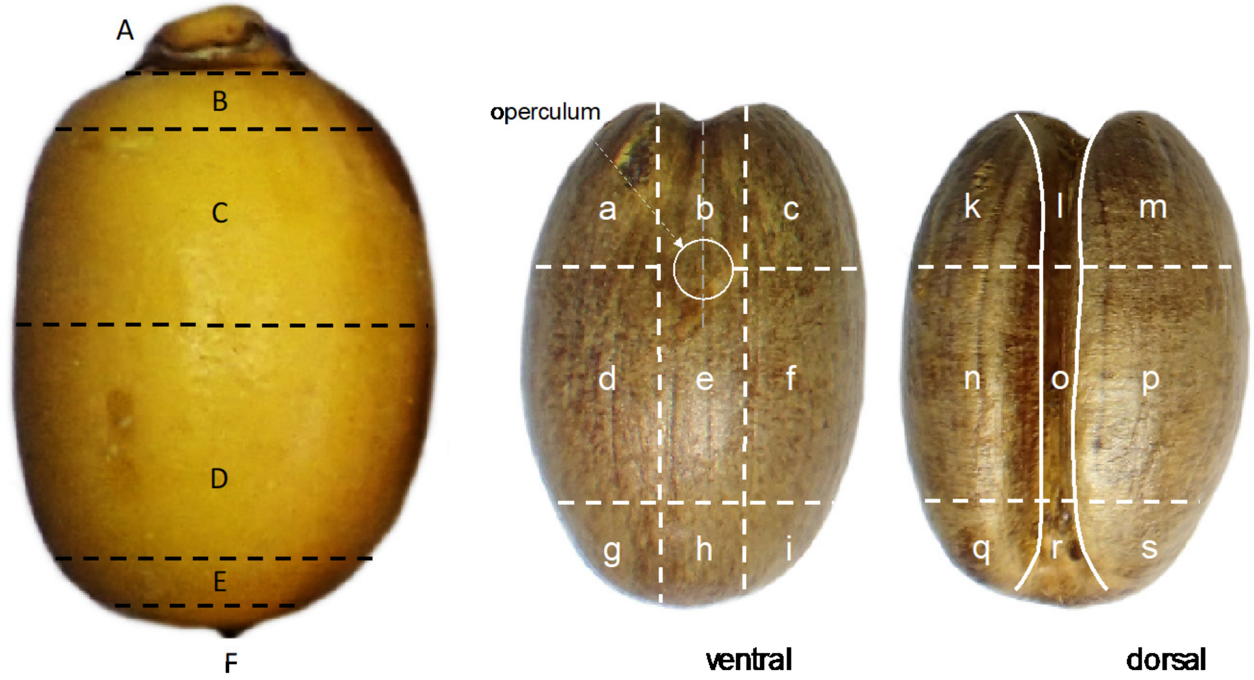

Fig. 1. Classification of the location of the initial predation hole. Left full *Phoenix canariensis* drupe, right seed only.

Discussion

Previous studies of the location of penetration holes in single, de-fleshed *Phoenix canariensis* seeds had revealed clear patterns in the establishment of breeding galleries (Spennemann, 2020c, 2021b). In these studies, the dorsal grove was favoured, accounting for 83.6% of all penetrations. That was attributed to biomechanics (Spennemann, 2021a) and the greater level of traction that the beetles could attain compared to the smoother ventral and lateral sides (Spennemann, 2021b).

When considering drupes, with their seeds still encased in the epicarp, there should be no significant difference between the ventral and the dorsal sides if we set aside the sector of the pedicel scar as that provides the beetles with traction. The experimental data bear out this hypothesis (Table 3).

Table 3. Frequency (in %) of the location of the initial predation hole in *Phoenix canariensis* seeds (n=100). Significance in the difference between penetrations of the mirrored sectors of the ventral and dorsal side. Significance coding: * p≤0.05; ** p≤0.01; *** p≤0.001. Fig. 1 for location codes.

ventral		dorsal		ventral
sector	penetrations	sector	penetrations	vs dorsal
a, c	8	k, l	6	
d, f	7	n, p	11	
e	4	o	1	
g, I	3	q, s	4	
h	1	r	3	

Fig. 2. Penetration of a drupe in sector D (a, b) in progress (48 hours after exposure), showing resultant penetration in sector f of the seed (c). The abdomen of the beetle is clearly visible (c–e).

While the presence of the pedicel scar clearly favours penetration at that part of the drupe, it is worth noting that sector l dominates with 51% of penetration holes, whereas the corresponding sector on the ventral side (sector b) only exhibits 7% of the penetration holes (Table 2). Given that 52% of the beetles can penetrate the seed from all other directions, other factors must be at work that ‘guide’ the beetle into the dorsal groove. It can be speculated that this may be due to reduced resistance of the endocarp that fill part of the groove.

When comparing the penetration of the seeds both while still surrounded by epicarp (i.e. in the drupe) and as de-fleshed seeds, the same preference for sector l can be observed, with 51.8% of penetration holes in drupes occurring in the sector and 58.2% of penetration holes in de-fleshed seeds. On de-fleshed seeds the morphology of sectors l and r differs, with sector l exhibiting a more canyon-like microtopography that is more favourable in affording traction to a beetle than the more open microtopography of the other sector.

Given the similarity in the location of the penetration holes of both seeds penetrated while still surrounded by epicarp and seeds penetrated in de-fleshed form, it is not possible to determine whether single seeds encountered on the ground were penetrated while still on the tree or while encountered on the ground.

While very significant differences exist in some sectors (Table 4), the overall numbers are so small that only one additional seed (among the single seeds cohort) would invalidate that significance level. The single exception is the penetration in sector r, which is highly significantly more commonly penetrated among single seeds ($\chi 2$= 13.0122, df=1; p = 0.0003095).

Table 4. Frequency (in %) of the location of the initial penetration hole in *Phoenix canariensis* seeds. Significance in the difference between the seeds penetrated while still surrounded by epicarp (in drupes, this experiment) and as de-fleshed seeds (Spennemann, 2021b, experiments #3 and #4). Significance coding: * p≤0.05; ** p≤0.01; *** p≤0.001. Fig. 1 for location codes.

Side	sector	seeds in drupes	single *seeds*	drupes *vs.* single seeds
ventral	a	1.0	1.4	
	b	7.0	2.1	
	c	1.0	1.4	
	d	4.0	—	***
	e	4.0	2.1	
	f	3.0	—	***
	g	1.0	—	***
	h	1.0	1.4	
	i	2.0	0.7	
dorsal	k	2.0	0.0	
	l	51.0	58.2	***
	m	4.0	0.7	
	n	5.0	1.4	
	o	1.0	8.9	**
	p	6.0	0.7	*
	q	—	—	
	r	3.0	21.2	***
	s	4.0	—	***
n		100	146	

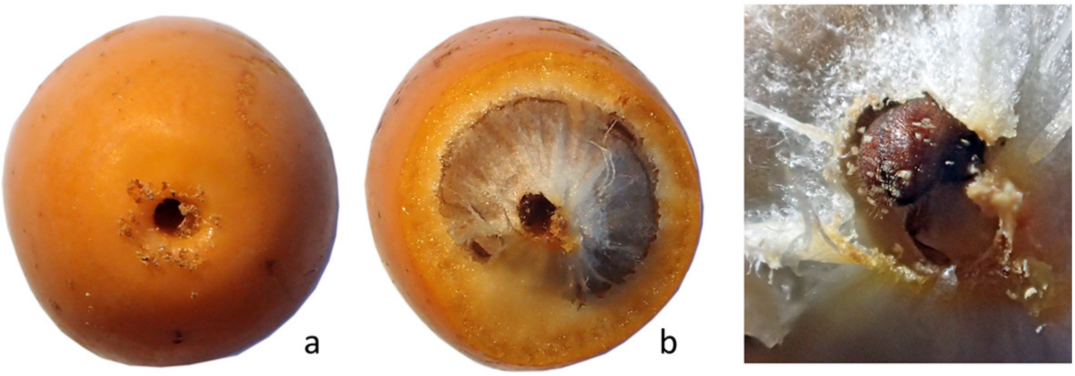

Fig. 3. Penetration of a drupe in sector A (a) in progress (48 hours after exposure), showing resultant penetration in sector l of the seed (b). The abdomen of the beetle is clearly visible (c).

Conclusions

The experiment has shown that the location of the initial penetration of *Phoenix canariensis* seeds does not occur at random, but is governed by the morphology of the drupe, and the microtopography that the drupe offers the beetle to find traction while gnawing into a drupe's pericarp. While most of the surface is smooth, the uneven surface of the pedicel scar offers the beetle the opportunity to stem off its hindlegs and provide the required traction to be able to push its mandibles into the epicarp of the seed. Once penetration of the pericarp has occurred, tunnelling follows the path of least resistance, leading to the penetration of the seed occurring at the proximal end of the distal groove. In settings where the drupe is still on the palm, it will be attached to the florescence via the pedicel. This will provide the opportunity to stem off its hindlegs and provide the required traction. This implies that there is no opportunity to prevent penetration once the beetle has physically reached the drupe on the palm or on the ground.

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نفوذ سوسک هسته خرما *Coccotrypes dactyliperda* (Coleoptera, Curculionidae, Scolytinae) به میوه درخت *Phoenix canariensis*

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تاریخچه مقاله

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چکیده

سوسک هسته خرما (*Coccotrypes dactyliperda* Fabricius, 1801) در بذر خرما نقب زده و لاروهایش، ضمن تغذیه از آلبومین دانه، موجب ایجاد دالان‌های جدید می‌شود. در بررسی های قبلی که هدف آن بررسی محل نفوذ حشره در بذور بدون گوشت بود مشخص شد که حشره، شیار پشتی دانه را برای نفوذ ترجیح می‌دهد. در ادامه آن، در تحقیق حاضر، محل ترجیحی حشره برای نفوذ در میوه‌های کامل بررسی شد. این مطالعه در ۱۰۰ تکرار، هر تکرار شامل یک میوه کامل به همراه یک حشره انجام شد. این مطالعه نشان داد که سوسک‌ها ترجیح می‌دهند که در شیار پایک نفوذ کنند، در حالی که تمام بخش‌های دیگر به طور قابل‌توجهی کمتر مورد حمله قرار می‌گیرد. در نوشتار حاضر، شیوه تغذیه حشره و پیامدهای آن مورد بحث قرار گرفته است.

کلمات کلیدی: اسپرماتوگونی، رفتار تغذیه، حرکت، الگوی فعالیت، نخل، زیست‌شناسی حشره

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