Journal of Insect Biodiversity and Systematics 08 (2), 191–205 *https://jibs.modares.ac.ir*

OPEN ACCESS

Tarbiat Modares University Press **Research Article** https://doi.org/10.52547/jibs.8.2.191 **ISSN**: 2423-8112

Entomological Society of Iran *http://zoobank.org/urn:lsid:zoobank.org:937391AD-8979-415E-8AF7-33F5CBBF305D*

Dispersal of the date stone beetle *Coccotrypes dactyliperda* (Coleoptera, Curculionidae, Scolytinae) in a managed rural landscape

Dirk HR Spennemann

Institute for Land, Water and Society; Charles Sturt University; PO Box 789; Albury NSW 2640, Australia.

✉*dspennemann@csu.edu.au*; https://orcid.org/0000-0003-2639-7950

ABSTRACT. There are only limited experimental or observational data on vertical and horizontal flight capacity of *Coccotrypes dactyliperda* Fabricius, 1801 (Coleoptera, Curculionidae, Scolytinae), a major pest in date palm plantations throughout the Mediterranean and Middle East. This paper provides a set of proxy data, using actual observations of colonisation rates of *Phoenix canariensis* (Chabaud, 1882) (Arecales, Arecaceae) seeds in a linear planting array at Alma Park (NSW, Australia). The majority of dispersal movements occurs between adjacent or near adjacent seeds, followed by palms in close proximity with movements less than 4–5 m. While the maximum observed dispersal distance is 350 m, data suggest that a 36 m gap between two groups of palms is beyond the flight/dispersal range of most *C. dactyliperda* individuals and that colonisation over such distances would be a rare event. Since seed location is aided by temperature-sensitive alcohol-mediated kairomones, the chances of a beetle finding a new seed to colonise over longer distances are increasingly diminished during the summer months, thereby reducing reproductive success.

Key words: dispersal, flight distances, kairomones, seed shadow

Received: 25 October, 2021

Accepted: 14 February, 2022

Published: 09 March, 2022

Subject Editor: Javad Karimi

Citation: Spennemann, D.H.R. (2022) Dispersal of the date stone beetle *Coccotrypes dactyliperda* (Coleoptera, Curculionidae, Scolytinae) in a managed rural landscape. *Journal of Insect Biodiversity and Systematics*, 8 (2), 191–205.

INTRODUCTION

Coccotrypes dactyliperda (Fabricius, 1801) (Coleoptera, Curculionidae, Scolytinae) is a cryptic spermatophagus beetle of the Curculionidae family, with females measuring 1.9 to 2.2 mm in length and about 0.7 to 1 mm in width. Males are about two thirds of the size. The beetle, which has a convex appearance and is hairy across the dorsal surface, ranges in color from reddish brown to almost black-brown (Fabricius, 1801; Letzner, 1840; Eichhoff, 1879; Schedl, 1961). As with other herbivorous cryptoparasites, the entire life cycle of *C. dactyliperda* occurs inside the seed (Blumberg & Kehat, 1982). After emergence from hibernation, the first generation of female beetles to leave the brood chamber (gallery) emerges during late December/early January in the southern hemisphere (late July/early August in the northern hemisphere) and attacks green drupes of the date palm (*Phoenix dactylifera* L., 1783 [Arecales, Arecaceae]), causing the bulk of these to abscise one to two days later (Blumberg, 2008). The species also predates the seeds of fallen dates, often after the pericarp has been consumed by other animals, such as rodents. This continues until August, when a second generation emerges from the seeds. The rate of abscission varies, but when the infructescences are not protected from beetle attack by chemical

Corresponding author: Spennemann, D.H.R., E-mail: *dspennemann@csu.edu.au*

or physical (bags) means, production losses usually range between 20 and 40% (Kehat et al., 1976; Hussein, 1990). *Coccotrypes dactyliperda* also attack other palms, in particular the Canary Island date palm (*Phoenix canariensis* (Chabaud, 1882) (Arecales, Arecaceae)) in a similar manner (for review of the beetle species see Spennemann, 2019a).

Initially distributed in the Middle East and North Africa as part of the date palm horticultural complex, the distribution range of the species has seen a remarkable increase during the nineteenth century, mainly due to the trade in dates as fruit for human consumption; the distribution of palm seeds (in particular *Phoenix canariensis*) for horticultural endeavours; and in the form of vegetable ivory for button manufacture. Today, *C. dactyliperda* has become a true cosmopolitan species that can be found in most subtropical and temperate zones (Spennemann, 2018b). The dispersal of the beetle is effected by external transport of an inhabited seed or via movement of the beetle itself. External transport of seeds (in which *C. dactyliperda* have established brood galleries) can be facillitated by humans during seed transport of on occasion of tree-translocation operations, as well as through transport in the gastro-intestinal tract of vertebrate vectors (Spennemann, 2018c). Experimental studies have shown that *C. dactyliperda* are likely to survive passage through the gastro-intestinal tract (Spennemann, 2020d). When searching for new host locations, *C. dactyliperda* vacate their host seeds and will react to kairomones from date seeds, especially their alcohol mediated fractions (Meisner et al., 1985; El-Barbary et al., 2002). The species of *Coccotrypes* disperse via flight and have been repeatedly and widely caught in flight interception traps baited with ethanol (Beaver & Löyttyniemi, 1991; Atkinson & Peck, 1994; de Abreu et al., 2012; Mazón et al., 2013; Pinheiro & Flechtmann, 2015; Comparini et al., 2018).

Coccotrypes dactyliperda is not a ready flyer but takes to flight when crowded or disturbed. The majority of the flights appear to be short-distance hops of 150 mm or less (El-Sufty & Helal, 1998, Spennemann et al., 2018). Given that *P. dactylifera* as the original host of *C. dactyliperda* is a prolific seeder, and given that the majority of seeds fall within 1.5 m of the trunk (Bar-Shalom & Mendel, 2001), such behaviour can be advantageous. Colonisation of non-abscised drupes or the infructescences in the crown of a palm occurs by crawling up the stem (El-Sufty & Helal, 1998) and by flight. There are only limited observational data on vertical and horizontal flight capacity of *C. dactyliperda*. Experimental observations showed that the beetle would primarily penetrate drupes on the ground and at lower levels. Palms growing at a height of 5–7 m were still affected to some degree (Hussein, 1990), with 8 m being regarded as the edge of capacity. Badawi et al. (1977) showed for other (physically larger) insect pests of date palms that penetration at 8 m had dropped to less than 2%. Some data on horizontal flight distances can be gleaned from a study on seed dispersal and infestation which documented flight distances of ~50 m (*Coccotrypes* sp. in Columbia: Ramírez et al., 2009). Experiments with similar sized bark beetles provide data that can inform on the flight capacity of *C. dactyliperda* as there are no biomechanical reasons that like-sized Scolytid beetles should perform substantively differently. In laboratory experiments, for example, walnut twig beetles (*Pityophthorus juglandis* Blackman 1928, *Dendroctonus ponderosae* Hopkins, 1902 [Coleoptera, Curculionidae, Scolytinae]) mounted to a flight mill flew on average 158 m (median) with maximum single flight of 1.2 km. A maximum total flight distance of 3.6 km in a 24 hr period was observed (Kees et al., 2017). Bark and ambrosia beetles fly at speeds of less than 1m/sec (Menocal et al., 2018). Given the paucity of data, there is a need to examine the flight capacity either by experimentation or by observation.

The Alma Park area (NSW, Australia) has been the focus of a study of Canary Island date palms in a rural setting looking at aspects of dispersal and seed variability as well as vectors of dispersal and their contribution to the germination success (Spennemann, 2018c; Spennemann & Pike, 2019). Seeds had been sampled from all trees at that site to assess their germination potential (Spennemann et al., 2018) with several seeds showing the evidence of breeding *C. dactyliperda*. The fact that the palm trees are aligned in a linear array permits to analyse their dispersal spatially and by implication to examine the beetle's flight potential in a natural, rather than a laboratory setting. The aim of this paper is to examine

the presence and extent of seed colonisation in a series of palms (Fig. 1A), in order to assess the dispersal ranges of the beetles. This will inform a model of population growth over time.

MATERIAL AND METHODS

Study area

The study area of Alma Park, a dispersed rural settlement without a commercial core or formal village centre, is located in the Southern Riverina of New South Wales, some 12 km northeast of Walla Walla and 24 km southwest of Henty. The environment is dominated by cleared farmland (sheep, wheat) with isolated farm trees and remnant vegetation (*Eucalyptus* spp.) along roadside corridors. Small patches of remnant but grazed bushland remain. Four discrete locations of palms exist in the immediate study area (Fig. 1A), three of which are planted (Glenalvon, Alma Park church and Netherlands) and one is animal dispersed (D14, S1–S3) (Fig. 1A). All but palms S1–S3 have become dispersal centres. There are three palms at the Glenalvon homestead as well as a group of seventeen palms lining the north-eastern section of a driveway leading to the house (35°35'01.7"S 146°47'04.5"E). Planted in the late 1940s or early 1950s, these palms are the remnants of an alley of palms that once lined both sides of the entire driveway (ca 80 palms). The missing palms have been sold as mature plants to a Melbourne nursery business (Spennemann, 2020c). Some 2.2 km south-east of Glenalvon is Alma Park Church, which has two groups of four palms each, one in front of the church (35°36'16.3"S 146°47'29.4"E) and the other in front of the church hall (35°36'16.3"S 146°47'29.4"E) (Spennemann, 2020a). Some 340 m to the south-east of the church is the Netherlands homestead (35°36'26.6"S 146°47'46.5"E), which at its entrance has two female plants dating to the late 1940s or early 1950s (Spennemann, 2020b). Palm D14 on the other hand is an animal-dispersed female plant some 6.3 km south-southwest of the church (35°38'18.1"S 146°45'52.2"E) which itself has become a seed source for further dispersal. In addition, along roadsides and bushland there are in excess of 1,800 animal-dispersed, naturally grown palms of varying ages (unpubl. data). Some of these are mature and allow the identification of their sex. One of these, an approximately twelve-year old plant (S1) is close to the gate of Glenalvon (350 m south-southwest), while two others (S2, S3) are along roadsides 1 km and 1.2 km to the south-west, respectively (Fig. 1B).

Detecting the presence of *Coccotrypes dactyliperda*

As part of a germination study (Spennemann & Pike, 2019), grab samples of seeds were collected in early May 2018 under some of the female palms at the driveway Glenalvon, Alma Park Church, Netherlands and D14. Some of these seeds proved to be penetrated by *Coccotrypes dactyliperda* as evidenced by frass (2A) as well as emerging beetles (Spennemann, 2018a). In addition, grab samples were collected in late November 2018 under the palms at the Glenalvon homestead as well as the female palms S1, S2 and S3. The seeds of these samples were carefully examined for borer holes. Any suspected holes were confirmed by scraping (Fig. 2B) with the seeds eventually split to determine the extent of perforation and to expose any galleries.

Size of brood emerging from colonised samples

As part of a comparative assessment of their germination potential, *Phoenix canariensis* seeds from various locations were placed between moist paper tissues in 110 x 165 x 35 mm plastic take-away containers, which in turn were placed in a room with an individually controlled stable temperature of 28°C. Evidence of frass (Fig. 2A) showed the number of seeds colonised by *Coccotrypes dactyliperda.* The take-away containers were checked on a weekly basis for five weeks (for the methodology of the germination expeiment, see Spennemann & Pike, 2019) and all beetles that had emerged from the seeds during the previous week were counted and removed.

Figure 1. Aerial image of the Glenalvon property: **A.** The setting of the palm clusters at Alma Park; **B.** Palms with identification numbers, sex and presence of *Coccotrypes dactyliperda*, Palms 18–19 and S1–S3 are female, palm 20 is male.

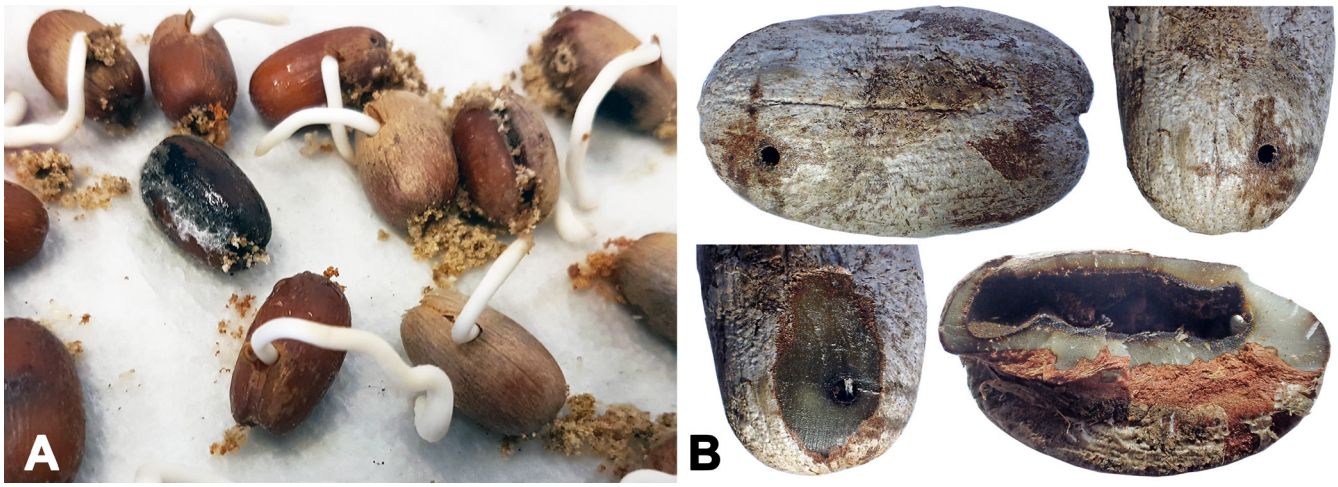

Figure 2. Seeds of *Phoenix canariensis*. **A.** Frass emerging from a seed during a germination experiment; **B.** Infested seeds, scraped for confirmation of bore hole (below, left) and split exposing gallery (below, right).

Statistics and modelling

The significance in the difference of observed proportions of seeds with evidence of breeding was determined by Fisher's exact test using an online calculator (MedCalc Software, 2018). The correlation coefficient of the relationship between the number of beetles emerging per seed and the rate of infestation of the palm was calculated using MS Excel. The modelling presented in Table 3 was carried out in MS Excel using the set sizes of starting broods, experimentally observed reproduction rates, and set mortality rates (see text for values).

RESULTS

The presence of *Coccotrypes dactyliperda* in the Alma Park area is confined to Glenalvon, with penetrated seeds encountered along the driveway, one of the palms at the homestead and the roadside palm closest to the driveway (S1). None of the other locations showed evidence of penetration (Table 1). Although a mere remnant of its former glory, the Glenalvon driveway is a closely and regularly spaced network of palms. For the purposes of this study, we only need to be concerned with the female plants as they drop seed. Among these, the greatest linear distance (36 m) occurs between the female palms 11 and 13, with one palm missing in-between palms 11 and 12 (Fig. 1A, Fig. 3). Depending on whether the palm existed at the time of penetration, the maximum distance to be covered was 24 m if the missing palm was female and 36 m if the missing palm was male. Given that palms as far afield as 390 m (S1) are infested, this gap appears to be negligible. Yet, the spatial distribution of penetration at Glenalvon shows a northern cluster of three palms with a high percentage of penetration seeds with rates of 17.8% and more (palms 13, 15 and 17), and much lower rates (6% or less) among the remainder of the palms to the south of the gap (Fig. 4). The difference in the rate of infestation between the lowest value of the northern group (palm 13, 17.8%) and the highest value of the remainder (palm 5, 6%) is statistically very significant (Fisher's exact test, 2-tailed; p=0.0004).

Table 1. Rate of infestation of the palms examined for the study.

Groups	Palm	% seeds penetrated	n (of seeds)
Glenalvon (planted)	1	1.0	192
	3	1.6	123
	5	6.0	200
	7	2.8	214
	8	0.6	173
	9	2.2	225
	11	0.0	170
	13	17.8	191
	15	41.7	60
	17	23.9	218
	18	0.0	112
	19	1.8	113
Alma Park Church (planted)	1	0.0	176
	2	0.0	270
	3	0.0	226
	5	0.0	188
	6	0.0	180
	8	0.0	300
Netherlands (planted)	north palm	0.0	150
	south palm	0.0	180
Self-Seeded	D14	0.0	136
	S1	0.9	107
	S2	0.0	104
	S3	0.0	98

Table 2 sets out the average number of beetles per penetrated seed at the end of the germination experiment after 5 weeks. The numbers per beetles emerging from seeds per palm range from as low as 4.6 individuals to a maximum of 25.5 (Table 2). Other experiments suggest that about 60% of the final brood size has been reached at that point (Spennemann, 2018a). The relative breeding success as expressed in the number of beetles shows no discernible spatial pattern. Also, as expected, breeding success as measured in the number of beetles emerging per seed is independent of the rate of infestation of that palm (correlation coefficient, R^2=0.1667).

Table 2. Average number of beetles hatching per seed in the germination experiment.

Palm	seeds colonised	beetles emerged	beetles / seed
1	2	43	21.5
3	2	36	18.0
5	12	252	21.0
7	6	36	6.0
8	1	21	21.0
9	5	23	4.6
13	34	405	11.9
15	25	638	25.5
17	52	1013	19.5

Palm	S1	L1	L2	L3	L4	L5	L6	L7	L8	L9	L10	L11	L12	L13	L14	L15	L16	L17	L18	L19
all		353	12	11	12	11	12	12	11	12	12	12	24	12	11	13	12	11	119	22
♀		353	23		23		24		11	12	24		36		24		23		119	22

Figure 3. Distances between all palms and between female palms only.

DISCUSSION

Coccotrypes dactyliperda is not endemic to Australia, but must now be regarded as naturalized (ALA, 2022). Even though there are other mature female *Phoenix canariensis* in the Alma Park area (Fig. 1A), the presence of *C. dactyliperda* is confined to the property Glenalvon and the adjacent roadway (palms S1–S3), with the highest number of penetrated seeds encountered underneath palms along the property's driveway. This strongly suggests a single-point of introduction at that property. The original infestation of these palms by *C. dactyliperda* must have occurred either at the nursery from which the palms were sourced or at the driveway itself. It is unlikely that the palms of the driveway would have been planted as mature trees. Rather they would have been planted as 2–3 year-old potted stock as was common in the trade at the time. Given the short lifespan of the beetle (less than 150 days including hibernation) and the duration of the palms to reach maturity (5–8 years), it is therefore extremely unlikely that the beetles could have arrived concurrent with the initial planting event. This indicates a colonisation at a later stage.

When planted in the late 1940s or early 1950s, the entire length of the driveway was lined on both sides with palms, giving a total of about 80 palms. The majority of these were purchased in the late 1990s and early 2000s by a Melbourne nursery (A. Lieschke, pers. comm.). That company purchased mature palms from numerous properties in northeastern Victoria and the Southern Riverina and transplanted them as landscaping trees to locations throughout metropolitan Melbourne (S. Booth,

pers. comm.). While speculative, it is plausible that the truck that removed the palms may have carried affected palms before and that one or more penetrated seeds fell off the truck during the loading and removal operations at Alma Park. This assumption is somewhat confirmed by the fact that the concentration of penetration seeds is by far the greatest at the northern end of the driveway (Fig. 4), which is next to a wide open space that allows for the turning of machinery and trucks. The last palms to be sold had been sourced in 2003 or 2004 from the western side of the top end of the drive, opposite the area of major infestation (A. Lieschke, pers. comm.).

Modelling the population development

Assuming a single penetrated seed arrived at Glenalvon, we can conceptualize and thus model the population increase and thus, roughly estimate the age of infestation. The female progeny tends to mate with its male siblings or fathers while still in the brood chamber, so that primarily fertilized females will emerge and move on to colonise new seeds (see review in Spennemann, 2019a). Thus the generational logic and thus speed of reproduction will depend on whether the founding female was fertilized (Fig. 5A) or not (Fig. 5B). A food preference experiment observed a total progeny of 37.8±26.2 (median 35, range 6–93) (n=46) adults derived from a single seed (Spennemann, 2018a). Any mortality among dispersing *C. dactyliperda* is caused either by predation by birds (Spennemann, 2019a), by failure to find and colonise a new seed, or by environmental conditions. The latter include, in particular, high temperatures and low humidity, but also sustained temperatures below -10 °C (Spennemann, 2019b).

Figure 4. Aerial image of the Glenalvon property showing the level of infestation with *Coccotrypes dactyliperda*.

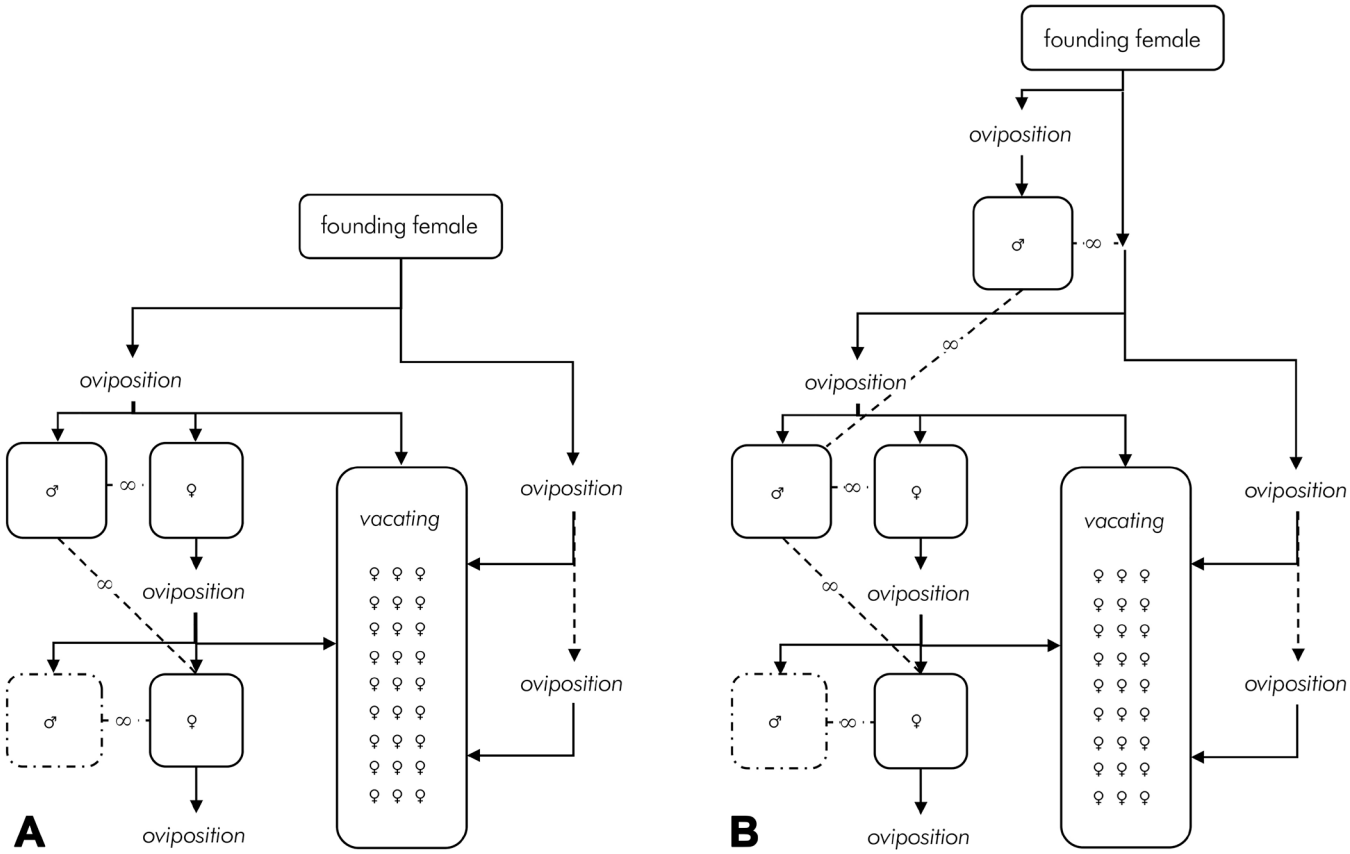

Figure 5. Intergenerational logics. **A.** Fertilized founding female; **B.** Unfertilized founding female.

Since actual mortality rates at Alma Park both during dispersal and after initial tunnelling are undocumented, models were run with 20%, 35%, 50%, 65% and 80% mortality. Based on extant evidence from the Middle East (see Spennemann, 2019a and references therein), it was posited that there would be three broods emerging from the first seed. Two of these broods would be able to colonise additional seeds, the first hatching two broods, one of which would colonise another set of seeds. All imagines would then hibernate (Fig. 6). The fact that unfertilized *C. dactyliperda* females can produce male offspring with which they then mate, allows the species to consistently reproduce (Herfs, 1950; Jordal et al., 2002; Holzman et al., 2009; Gottlieb et al., 2009, 2011). Modelling three broods per annum (Fig. 6) with a median (minimum) progeny of 35 (6) per seed shows that populations are stable at mortality rates of 98.67% (92.25%) above which they are on an extirpation trajectory (Table 3). Thus the beetle numbers should result in far higher infestation rates than actually observed. Even at the mortality rate of 90% with a low brood size of six, the beetle population would reach tens of millions in 3 years. The dry climate and low humidity during the summer months may limit the number of broods that can be raised. Modelling the population grown with only two broods, a mortality rate of 98.24% (89.62%) ensures a stable population with a median (minimum) progeny of 35 (6) per seed. Higher mortality rates will lead to gradual extirpation. Even with mortality rate of 75% with a low brood size of six, the beetle population would reach tens of millions after 10 years (Table 4).

These modelled population numbers have a bearing on the understanding of the dispersal capacity of *C. dactyliperda* observed at Alma Park. The last sale and removal of a mature palm occurred in 2003 or 2004. Assuming this was the cause of infestation, then the actual observed distribution pattern is the result of approximately 15 years of dispersal. Given the modelled population numbers, the distribution of the beetle numbers and thus the level of infestation along the driveway should be more or less

uniform by now. Clearly, that is not the case (Table 1). Given the proximity of the palms, the uniform landscape and vegetation patterns at Alma Park, and the small size of the area, externalities that might affect the dispersal impact uniformly on the palms discussed here. That includes variations in temperature, humidity and wind, as well as the presence of potential predators. The palm trees at Glenalvon sit almost at a fence line between a grassed surface and a rather denuded paddock. This allows to assess the seed shadow both with and without bounce-effect on bare ground (Fig. 7). The seed shadow on the grassed area is confined to a radius less than the canopy of the crown, while the shadow on bare soil extends to the perimeter of the canopy. The crown radii of 3 to 3.5 m are less than the half-distance between the palms of 5.5 to 6 m between adjacent females and 12 m where females are separated by a male (Fig. 3). The uneven distribution of colonisation suggests that the vast majority of dispersal movements occurs between adjacent or near adjacent seeds and that for most movements a distance of 4–5 m acts as an effective threshold that prevents colonisation. The data also suggest that the 36 m gap between the northern group and the southern alignment is beyond the flight range of most *C. dactyliperda* individuals and that colonisation over such distances would be a rare event. The occurrence of penetration seeds in the southern portion as well as at the outliers, palm n° 19 (120 m) and S1 (353 m), however, cautions and shows that individual *C. dactyliperda* can traverse such distances. It is unclear to what extent such dispersal on pure flight capability or whether this is aided by winds. Given the rural location, local wind data are unavailable. According to the Australian Bureau of Meteorology, the closest weather stations are Albury (60 km SSE) (Bureau of Meteorology, 2022a); Narrandera (94 km NW) (Bureau of Meteorology, 2022b) and Wagga Wagga (48 km NE) (Bureau of Meteorology, 2022c). While are unsuitable for a detailed assessment of local conditions, they are informative. Broadly speaking, during the prime dispersal period (December to February) come primarily from the northeast in the mornings with 5–20% of the winds in excess of 10 km/h, and primarily from the west-southwest in the evenings with lesser speeds.

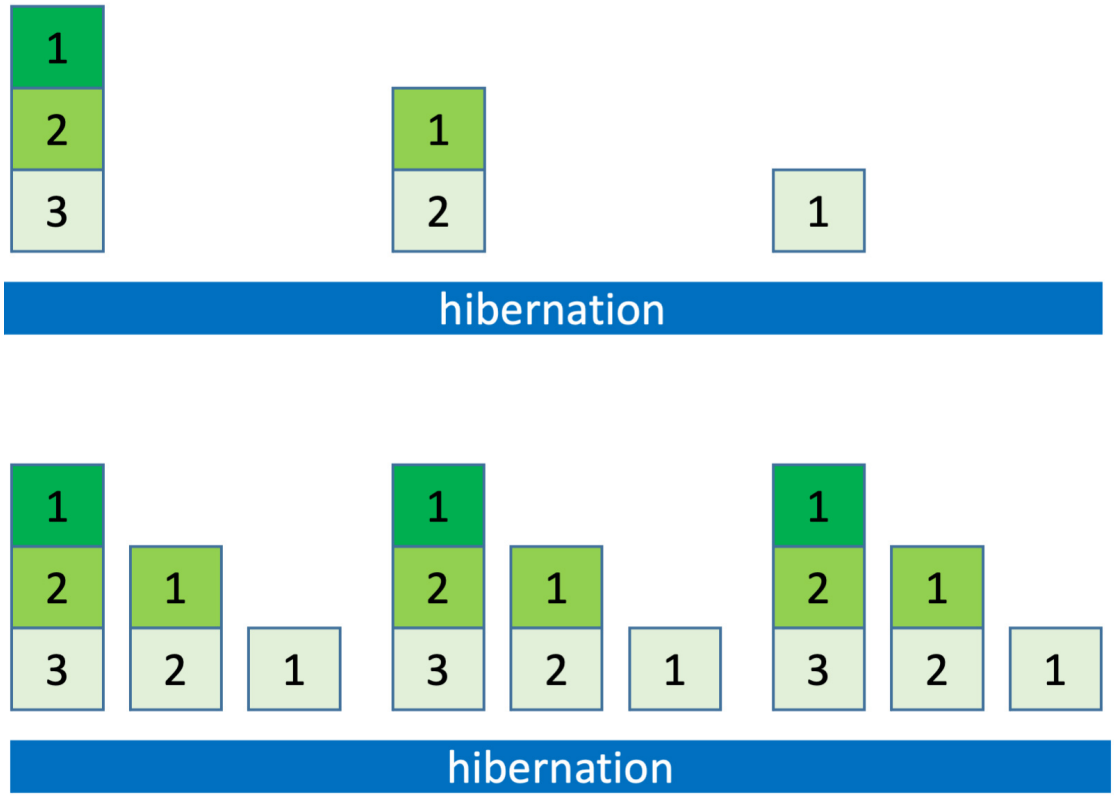

Figure 6. Generational model to the establishment of *Coccotrypes dactyliperda* populations.

Table 3. Population development from a single seed (Three broods per annum).

	Consistent Mortality							
Year	20	35	50	65	75	80	90	99
0	6	6	6	6	6	6	6	6
1	969	562	288	121	56	35	9	0
2	156,439	52,610	13,824	2,444	527	202	14	0
3	25,260,557	4,926,308	663,552	49,315	4,944	1,176	22	0
4	4.08E+09	461,294,545	31,850,496	995,227	46,349	6,827	33	0
5	6.59E+11	4.32E+10	1.53E+09	20,084,668	434,518	39,654	51	0
0	35	35	35	35	35	35	35	35
1	824,180	449,135	209,628	75,272	29,113	15,680	2,481	22
2	1.94E+10	5.76E+09	1.26E+09	1.62E+08	24,216,011	7,024,640	175,814	14
3	4.57E+14	7.40E+13	7.52E+12	3.48E+11	2.01E+10	3.15E+09	12,460,838	9
4	1.08E+19	9.49E+17	4.50E+16	7.49E+14	1.68E+13	1.41E+12	8.83E+08	6
5	2.53E+23	1.22E+22	2.70E+20	1.61E+18	1.39E+16	6.32E+14	6.26E+10	4

Table 4. Population development from a single seed (Two broods per annum).

	Consistent Mortality							
Year	20	35	50	65	75	80	90	99
0	6	6	6	6	6	6	6	6
1	167	115	72	39	23	16	6	0
2	4,650	2,191	864	254	84	42	6	0
3	129,467	41,873	10,368	1,655	316	110	5	0
4	3,604,360	800,192	124,416	10,776	1,187	291	5	0
5	100,345,385	15,291,662	1,492,992	70,155	4,449	769	5	0
0	35	35	35	35	35	35	35	35
1	28,420	18,911	11,331	5,681	2,986	1,960	551	17
2	23,077,040	10,217,816	3,668,492	922,087	254,738	109,760	8,682	8
3	1.87E+10	5.52E+09	1.19E+09	149,666,273	21,732,318	6,146,560	136,744	4
4	1.52E+13	2.98E+12	3.85E+11	2.43E+10	1.85E+09	344,207,360	2,153,725	2
5	1.24E+16	1.61E+15	1.24E+14	3.94E+12	1.58E+11	1.93E+10	33,921,171	1

It can be surmised that in dry environments the alcohol-mediated kairomones will have a shorter shelf life, with the epicarp of a date seed rapidly drying out. This is supported by the observation that *C. dactyliperda* prefer fresh seed over dry seed (Spennemann, 2018a). Therefore, the chances of a beetle finding a new seed to colonise over longer distances are increasingly diminished during the summer months, thereby reducing reproductive success.

The spermatophagus beetle *Coccotrypes dactyliperda* is a prolific breeder that, depending on mortality, can build up a large population in a short time. As noted earlier, the beetles will take flight when disturbed or when in crowded situations and will then seek out new host seeds guided by pheromones emitted from the seed. This observational study has shown that while the beetle is capable of dispersing at least as far as 350 m, the majority of movements is less than 36 m. There is a need to understand the absolute physiological flight capacity as measured on a flight mill, as well as the environmental flight capacity relative to the influences of wind, humidity and temperature. Since the successful colonisation of a new seed is primarily subject to the capacity of *C. dactyliperda* to detect the existence of a new seed, there is a further need to experimentally assess the ability of *C. dactyliperda* to detect kairomones at larger distances.

Figure 7. Seed shadow cast by palm nº 5, Glenalvon, Alma Park.

AUTHOR'S CONTRIBUTION

D.H.R.S. designed and performed all practical aspects of the work and writing the manuscript. He read and approved the final version of the manuscript.

FUNDING

This research received no external funding.

AVAILABILITY OF DATA AND MATERIAL

Not applicable.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

Not applicable.

CONSENT FOR PUBLICATION

Not applicable.

CONFLICT OF INTERESTS

The author declares that there is no conflict of interest regarding the publication of this paper.

ACKNOWLEDGMENTS

I am indebted to Anthony and Dale Lieschke as well as Gavin Kotzur (all Alma Park) for permitting repeated access to the Glenalvon and Netherlands properties. Steve Booth (Silvan, Victoria) kindly provided information on the purchase and removal of palms from the Walla Walla and Alma Park area in the late 1990s and early 2000s.

REFERENCES

AAL. (2022) *Coccotrypes dactyliperda* (Fabricius, 1801) [Online]. Canberra: Commonwealth Scientific and Industrial Research Organisation. Available at: https://bie.ala.org.au [Accessed 31th January 2022].

Atkinson, T.H. & Peck, S.B. (1994) Annotated checklist of the bark and ambrosia beetles (Coleoptera: Platypodidae and Scolytidae) of tropical southern Florida. *Florida Entomologist*, 77, 313–329. https://doi.org/10.2307/3496101

Badawi, A.I., Saleh, M.R. M. & Kamel, A.H. (1977) Susceptibility of different date varieties to infestation with certain pests and the effect of tree height on the rate of infestation. *Agricultural Research Review,* 55, 9–13.

Bar-Shalom, O. & Mendel, Z. (2001) Seasonal changes in the seed bank in date palm (*Phoenix dactylifera*) orchards and the involvement of the date-stone beetle (*Coccotrypes dactyliperda*). *Phytoparasitica*, 29, 84–85.

Beaver, R.A. & Löyttyniemi, K. (1991) Annual flight patterns and diversity of bark and ambrosia beetles (Col., Scolytidae and Platypodidae) attracted to bait logs in Zambia. *Journal of Applied Entomology*, 112**,** 505–511. https://doi.org/10.1111/j.1439-0418.1991.tb01084.x

Blumberg, D. (2008) Date palm arthropod pests and their management in Israel. *Phytoparasitica*, 36, 411–448. https://doi.org/10.1007/BF03020290

Blumberg, D. & Kehat, M. (1982) Biological studies of the date stone beetle, *Coccotrypes dactyliperda*. *Phytoparasitica,* 10**,** 73–78. https://doi.org/10.1007/BF02981129

Bureau of Meteorology (2022a) Climate statistics for Australian locations. Monthly climate statistics. Albury Airport (station nº 072146). Retrieved from http://www.bom.gov.au/climate/averages/tables/cw_072146.shtml [Accessed 13 February 2022].

Bureau of Meteorology (2022b) Climate statistics for Australian locations. Monthly climate statistics. Narrandera Golf Club (station nº 074221). Retrieved from http://www.bom.gov.au/climate/averages/tables/cw_074221.shtml [Accessed 13 February 2022].

Bureau of Meteorology (2022c) Climate statistics for Australian locations. Monthly climate statistics. Wagga Wagga AMO (station nº 072150). Retrieved from http://www.bom.gov.au/climate/averages/tables/cw_072150.shtml [Accessed 13 February 2022]

Comparini, C., Gallego, D., Núñez, L., Closa, A.M. & Salord, M.D.M.L. (2018) First record of four scolytid species (Coleoptera: Curculionidae) in the Balearic Islands (Western Mediterranean; Spain). *Journal of the Entomological Research Society,* 20, 61–70.

de Abreu, R.L.S., Ribeiro, G.D.A., Vianez, B.F. & Sales-Campos, C. (2012) Insects of the subfamily Scolytinae (Insecta: Coleoptera, Curculionidae) collected with pitfall and ethanol traps in primary forests of central Amazonia. *Psyche: A Journal of Entomology,* 2012, 480520. https://doi.org/10.1155/2012/480520

Eichhoff, W. (1879) Ratio, descriptio, emendatio eorum Tomicinorum qui sunt in Dr. Chapuisi et autoris ipsius collection et autoris ipsius collectionibus et quos praeterea recognovit. *Mémoires de la Société Royale des Sciences de Liege,* 8, 1–554.

El-Barbary, N.S., Donia, A.R. & Mostafa, A.M. (2002) Effect of food preference and extracts of the date palm fruits and stones on the activity of the adult females of the date stone beetle, *Coccotrypes dactyliperda* Fabricius (Coleoptera, Scolytidae). *Alexandria Journal of Agricultural Research*, 47, 103–107.

El-Sufty, R. & Helal, R.M. (1998) Studies on the date stone beetle, *Coccotrypes dactyliperda* F. (Col: Scolytidae) in North of Nile Delta. *Menofiya Journal of Agricultural Research,* 23, 1683–1692.

Fabricius, J.C. (1801) *Systema eleutheratorum secundum ordines, genera, species: adiectis synonymis, locis, observationibus, descriptionibus*. Bibliopoli Academici Novi, Kiliae, 2, 687 pp.

Gottlieb, D., Holzman, J., Lubin, Y., Bouskila, A., Kelley, S. & Harari, A. (2009) Mate availability contributes to maintain the mixed-mating system in a scolytid beetle. *Journal of Evolutionary Biology*, 22, 1526–1534. https://doi.org/10.1111/j.1420-9101.2009.01763.x

Gottlieb, D., Lubin, Y., Bouskila, A., Gordon, D. & Harari, A. (2011) Time limitation affects offspring traits and female's fitness through maternal oviposition behaviour. *Biological Journal of the Linnean Society,* 102, 728–736. https://doi.org/10.1111/j.1095-8312.2011.01606.x

Herfs, A. (1950) Studien an dem Steinnußborkenkäfer *Coccotrypes tanganus* Eggers. 2. Die Soziologie von *Coccotrypes tanganus*. *Höfchen-Briefe für Wissenschaft und Praxis* (Bayer Leverkusen), 3, 3–31.

Holzman, J.P., Bohonak, A.J., Kirkendall, L.R., Gottlieb, D., Harari, A.R. & Kelley, S.T. (2009) Inbreeding variability and population structure in the invasive haplodiploid palm-seed borer (*Coccotrypes dactyliperda*). *Journal of Evolutionary Biology,* 22, 1076–1087. https://doi.org/10.1111/j.1420-9101.2009.01722.x

Hussein, A.E. (1990) Date varieties and palm height in relation to infestation with date stone beetle, *Coccotrypes dactyliperda* F. (Coleoptera: Scolytidae). *Annals of Agricultural Science, Moshtohor*, 28, 2613–2622.

Jordal, B.H., Normark, B.B., Farrell, B.D. & Kirkendall, L.R. (2002) Extraordinary haplotype diversity in haplodiploid inbreeders: phylogenetics and evolution of the bark beetle genus *Coccotrypes*. *Molecular Phylogenetics and Evolution,* 23, 171–188. https://doi.org/10.1016/S1055-7903(02)00013-1

Kees, A.M., Hefty, A.R., Venette, R.C., Seybold, S.J. & Aukema, B.H. (2017) Flight capacity of the walnut twig beetle (Coleoptera: Scolytidae) on a laboratory flight mill. *Environmental Entomology*, 46, 633–641. https://doi.org/10.1093/ee/nvx055

Kehat, M., Blumberg, D. & Greenberg, S. (1976) Fruit drop and damage in dates: the role of *Coccotrypes dactyliperda* F. & nitidulid beetles, and prevention by mechanical measures. *Phytoparasitica,* 4, 93–99. https://doi.org/10.1007/BF02980340

Letzner, C.W. (1840) Ueber den *Bistrochus dactyliperda* und seine frühern Stände. *Uebersicht der Arbeiten und Veränderungen der Schlesischen Gesellschaft für Vaterländische Cultur in Jahre 1839*, 17, 116–120.

Mazón, M., Díaz, F. & Gaviria, J.C. (2013) Effectiveness of different trap types for control of bark and ambrosia beetles (Scolytinae) in Criollo cacao farms of Mérida, Venezuela. *International Journal of Pest Management,* 59, 189–196. https://doi.org/10.1080/09670874.2013.810794

MedCalc Software (2018) MEDCALC. Fisher exact probability calculator. Ostend, Belgium, Available at: https://www.medcalc.org/calc/fisher.php [Accessed 31th January 2022].

Meisner, J., Weissenberg, M., Blumberg, D. & Ascher, K.R.S. (1985) Date palm fruit stone extracts as phagostimulants for the adult date stone beetle, *Coccotrypes dactyliperda* F. (Coleoptera: Scolytidae). *Zeitschrift für Pflanzenkrankheiten und Pflanzenschutz,* 92, 305–309.

Menocal, O., Kendra, P.E., Montgomery, W.S., Crane, J.H. & Carrillo, D. (2018) Vertical distribution and daily flight periodicity of ambrosia beetles (Coleoptera: Curculionidae) in Florida Avocado orchards affected by Laurel Wilt. *Journal of Economic Entomology,* 111, 1190–1196. https://doi.org/10.1093/jee/toy044

Pinheiro, G.C. & Flechtmann, C.A.H. (2015) Influence of fire on the diversity of Scolytinae and Platypodinae (Curculionidae) in Hevea Brasiliensis in São Paulo state (Brazil). *IV Congresso Brasileiro de Heveicultura*, *24–26 June 2015*. São José do Rio Preto.

Ramírez, B.H., Parrado-Rosselli, Á. & Stevenson, P. (2009) Seed dispersal of a useful palm (*Astrocaryum chambira* Burret) in three amazonian forests with different human intervention. *Revista Colombia Forestal,* 12, 5–16. https://doi.org/10.14483/udistrital.jour.colomb.for.2009.1.a01

Schedl, K.E. (1961) Scolytidae und Platypodidae Afrikas. *Revista de Entomologia de Mocambique,* 4, 355–742.

Spennemann, D.H.R. (2018a) An experimental evaluation of food preferences and associated hatching times of the date stone beetle, *Coccotrypes dactyliperda* (Scolytinae, Coleoptera). *Institute for Land, Water and Society Report.* Albury, NSW: Institute for Land, Water and Society, Charles Sturt University.

Spennemann, D.H.R. (2018b) Global distribution of the date stone beetle, *Coccotrypes dactyliperda* (Coleoptera: Curculionidae, Scolytinae). *Journal of Insect Biodiversity and Systematics* 4, 203–226.

Spennemann, D.H.R. (2018c) *Phoenix canariensis* seed encountered in scats and ejecta collected at Alma Park. Albury, NSW: Institute for Land, Water and Society, Charles Sturt University.

Spennemann, D.H.R. (2019a) Biology, ecology and distribution of the date stone beetle, *Coccotrypes dactyliperda* (Scolytinae, Coleoptera). *Zoology in the Middle East*, 65, 163–182. https://doi.org/10.1080/09397140.2019.1571743

Spennemann, D.H.R. (2019b) Resilience of the date stone beetle *Coccotrypes dactyliperda* (Coleoptera, Curculionidae), following periods of exposure to subzero temperature. *Turkish Journal of Entomology*, 43, 379–385. https://doi.org/10.16970/entoted.530263

Spennemann, D.H.R. (2020a) Background to the Palms at Alma Park (NSW) I: Alma Park Lutheran Church. Albury, NSW: Institute for Land, Water and Society, Charles Sturt University. https://doi.org/10.13140/RG.2.2.22160.84481

Spennemann, D.H.R. (2020b) Background to the Palms at Alma Park (NSW) II: Netherlands Homestead. Albury, NSW: Institute for Land, Water and Society, Charles Sturt University. https://doi.org/10.13140/RG.2.2.32227.17444

Spennemann, D.H.R. (2020c) Background to the Palms at Alma Park (NSW) III: Glenalvon Homestead. Albury, NSW: Institute for Land, Water and Society, Charles Sturt University. https://doi.org/10.13140/RG.2.2.28871.73127

Spennemann, D.H.R. (2020d) Resilience of breeding *Coccotrypes dactyliperda* (Coleoptera, Curculionidae, Scolytinae) to ingestion by vertebrates. *Turkish Journal of Entomology*, 44, 205–217. https://doi.org/10.16970/entoted.622103

Spennemann, D.H.R., Kent, K. & Cook, R. (2018) Uninvited guests: Mass Emergence of Scolytinid Beetles in a Seed Germination Experiment and its Management. *Institute for Land, Water and Society Report.* Albury, NSW: Institute for Land, Water and Society, Charles Sturt University.

Spennemann, D.H.R. & Pike, M. (2019) Rites of Passage: germination of regurgitated and defecated *Phoenix canariensis* seeds. *Proceedings of the Linnean Society of New South Wales,* 141, 49–59.

پراکندگی سوسک سنگی خرما *Coccotrypes dactyliperda* (Coleoptera: Curculionidae: Scolytinae) در یک چشم‌انداز روستایی مدیریت شده

دیرک اچ آر اسپنمن

موسسه خاک، آب و جامعه، دانشگاه چارلز استورت، صندوق پستی ۷۸۹، نیو سات ولز، استرالیا.
* پست الکترونیکی نویسنده مسئول مکـاتبه: *dspennemann@csu.edu.au*

| **تاریخ دریـافت:** ۰۳ آبان ۱۴۰۰ | **تاریخ پذیرش:** ۲۵ بهمن ۱۴۰۰ | **تاریخ انتشار:** ۱۸ اسفند ۱۴۰۰ |

چکیـده: اطلاعات تجربی و مشاهده‌ای بسیار کمی در مورد توان پرواز و انتشار عمودی و افقی سوسک *Coccotrypes dactyliperda* Fabricius, 1801 (Coleoptera: Curculionidae: Scolytinae)، به عنوان یکی از آفات مهم نخلستان‌ها در منطقه مدیترانه و خاورمیانه وجود دارد. این مقاله، یک سری اطلاعات متمرکز را بر اساس مشاهدات واقعی از نرخ استقرار روی بذور نخل جزایر قناری (*Phoenix canariensis* (Chabaud, 1882) (Arecales: Arecaceae)) که به صورت طولی در پارک آلما (واقع در نیوساوت ولز، استرالیا) کشت شده‌اند، فراهم می‌کند. انتشار آلودگی عمدتاً بین درختان چسبیده به هم یا بسیار نزدیک اتفاق می‌افتد و در مرحله بعد از آن درختان مجاور با فاصله کمتر از ۴–۵ قرار می‌گیرند. با وجودی‌که بیشترین فاصله مشاهده شده برای انتشار ۳۵۰ متر بوده، اطلاعات بدست آماده نشان می‌دهند که فاصله ۳۶ متر بین دو ردیف نخل فراتر از دامنه و توانایی انتشار جمعیت سوسک *C. dactyliperda* بوده و استقرار در چنین فواصلی بسیار به ندرت اتفاق می‌افتد. از آنجایی که حشره آفت، بذور هدف را بر اساس کایرومون‌های الکلی حساس به درجه حرارت پیدا می‌کند، شانس سوسک‌ها برای یافتن بذور در فواصل دورتر طی ماه‌های تابستان به شدت کاهش یافته و به همین لحاظ موفقیت آنها در تولید مثل نیز تنزل می‌یابد.

واژگـان کلیدی: پراکندگی، فواصل پرواز، کایرومون‌ها، انتشار بذر