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Flight and Landing Behaviour of *Prostephanus Truncatus* (Horn) (Coleoptera: Bostrichidae) In Relation to Wind Speed

HENRY Y. FADAMIRO*

Department of Zoology, University of Oxford, Oxford OX1 3PS, U.K.

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Abstract—The effect of wind speed on the flight and landing behaviour of *Prostephanus truncatus* (Horn) was investigated in a sustained-flight tunnel. Wind speeds were tested over a range of 0–32 cm/s. Wind was not necessary for take-off and the proportion of beetles taking flight slightly, but significantly decreased linearly with increasing wind speed. While the majority of the beetles that initiated flight flew and landed upwind at a low wind speed of 20 cm/s, higher wind speeds resulted in increased downwind flight and landing. Wind speed, however, exerted a lesser effect on type of flight, although a significantly higher proportion of beetles flying at 20 cm/s exhibited steady flight than those flying at the higher speed of 32 cm/s. Based on these results, a wind speed of no more than 20 cm/s is recommended for the study of the flight behaviour of *P. truncatus* The results are discussed in relation to the field ecology of the pest. Copyright © 1996 Published by Elsevier Science Ltd

Key words—Prostephanus truncatus, Larger grain borer, flight, landing, behaviour, wind tunnel, wind speed

INTRODUCTION

The Larger grain borer, *Prostephanus truncatus* (Horn), is an important introduced economic pest of farm-stored maize and dried cassava with an increasing range in Africa (Hodges, 1986). Its current distribution in Africa includes confirmed reports in 12 countries (Hodges, 1994). Although the spread of this beetle in Africa may be related to inter-country trade and inadequate plant quarantine regulations, flight is possibly a major consideration in its spread, and has been highlighted as an area requiring particular attention (McFarlane, 1988; Markham *et al*., 1991). Golob and Hodges (1982) were the first to indicate the possibility of spread of this insect by flight when they recorded movement of *P. truncatus* between field and store.

Like other bostrichids, *P. truncatus* is principally a wood borer (Chittenden, 1911), and there are recent reports on the widespread populations of the beetle now established in the natural environment (Nang'ayo *et al*., 1993; Tigar *et al*., 1994) suggesting the possible role of wood as an alternative host. Ramirez *et al*. (1991) indicated that the natural environment is used by the larger grain borer as a transient niche. It follows therefore that the movements of the pest between the natural enviroment and crop stores possibly occurs mainly by flight.

Thus, being a field-to-store pest, one factor that potentially may affect its flight behaviour and possibly trap catch is wind speed. In the scolytid, *Trypodendron lineatum* (Olivier), one of the few

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*Present address: Department of Entomology, Iowa State University of Science and Technology, 411 Science II Building, Ames, Iowa 50011, U.S.A.

beetles that have exhibited flight behaviour in a wind tunnel, trap catch decreases linearly with increasing wind speed (Salom and McLean, 1991). However, little is known about the effect of wind speed on the flight and landing behaviour of *P. truncatus*.

The wind tunnel studies reported here examined the effect of wind speed on take-off, flight direction, flight type, landing direction and flight duration of *P. truncatus*.

MATERIALS AND METHODS

Insect material

Insects used in this study were unsexed adult Tanzanian strains of *P. truncatus* (Natural Resources Institute, Chatham, Kent, U.K.) between 7 and 15 d old (Fadamiro *et al.*, 1996). Rearing of beetles was done on whole clean maize at 30 ± 1°C and 65 ± 5% r.h. under a L12: D12 photoperiod.

Wind tunnel

The study was conducted in a clear, rectangular, glass flight tunnel (Fadamiro, 1995), 160 cm long and 75 cm high and wide with moveable visual floor patterns. Four cool white fluorescent bulbs (85W), mounted 5 cm above the wind tunnel provided lighting and facilitated direct observations of flying beetles. Beetles were released on to a platform placed 25 cm from the downwind screen and 23 cm above the floor, facing the upwind direction. The release platform consisted of a plastic Petri dish 9 cm in diameter on to which was placed a plastic cone with sharp edges. The platform was roughened to enhance adherence and insects more readily took off while on the cone than any other part of the platform (personal observation). Air warming was by electrical heating of the air in the room prior to tests. Insects to be used were removed from a culture 3 h before flight observation, cleaned with a soft brush to remove maize dust, examined for damage, sexed, and allowed to acclimate in tunnel conditions for 20 min. Studies in the wind tunnel were carried out at 25 ± 1°C, 30 ± 2% r.h., during the last 2 h of the photophase under a light intensity of 2400 lux (Fadamiro, 1995; Fadamiro *et al.*, 1996). All observations and recordings were made manually.

Experimental protocol

The flight behaviour of *P. truncatus* was compared at three different wind speeds and in still air. The wind speed treatments (measured using an Anemometer TA400 by Airflow Dev. Canada) were 0, 20, 25, and 32 (± 1 cm/s). Ten pairs of insects (7 pairs for replicates 4 and 5) aged 7–15 d were randomly selected and released at each wind speed and observed for 5 min. There were eight replicates per treatment and beetles were used only once. The order of observations within a block was randomised. Observation parameters were similar to those measured by Salom and McLean (1991), and included the number taking-off (occurrence of flight), flight direction, overall flight type, direction of landing, and total flight time (measured as the time spent during flight using a stop watch to the nearest 0.01 s).

Direction of flight was the direction headed by the beetle at take-off and was scored as downwind, upwind, or nondirectional. A flight was scored as nondirectional when it was neither downwind nor upwind (in still air upwind was defined as the end of the wind tunnel furthest away from the release platform).

Overall flight type was scored as: steady (slow and stable flight along a narrow path that may have included more than one directional heading throughout the flight period); erratic (quick, sharp changes in movement, with no specific flight direction); and direct (fast, straight-line flight to some endpoint, with only one directional heading).

Landing direction was scored as downwind (if a beetle landed in the area 10 cm from the downwind screen), upwind (if a beetle landed in the area 10 cm from the upwind screen), or middle (if neither downwind nor upwind).

Statistical analysis

Data from speed and time measurements were expressed as actual numbers and transformed as necessary (mainly by square root transformation). Data on take-off were expressed as a proportion of the numbers of beetles released, while those on flight direction, flight type, and direction of landing were expressed as a percentage of the 'fliers' (i.e. those that took flight). Analyses were carried out using the GLM procedure in SAS (1985).

RESULTS

Using regression analysis, a linear model was determined to be the best fit of the data on the effect of wind speed on flight take-off ($F_{1,30} = 4.57$, $P = 0.04$). Although most of the variation in the data is not explained by the regression ($r^2 = 0.12$), the data suggest a slight trend of decreasing take-off with increasing wind speed (Fig. 1).

Flight direction varied with wind speed; there was a significant difference not only in the proportion of insects flying in the upwind direction ($F_{3,28} = 6.10$, $P = 0.003$), but also in the proportion flying downwind ($F_{3,28} = 6.00$, $P = 0.003$). There was no difference in the proportion of beetles making non-directional flight at all tested wind speeds ($F_{3,28} = 0.49$, $P = 0.69$) (Fig. 2). It is apparent from the data that at higher winds most beetles flew downwind, whereas they flew upwind at low wind speeds (Fig. 2).

Wind speed exerted a lesser effect on most classifications of flight type: the proportion flying erratically did not differ with wind speeds ($F_{3,28} = 1.52$, $P = 0.23$), and this was also true for the proportion making direct flights ($F_{3,28} = 1.76$, $P = 0.18$). A significantly higher proportion of beetles flying at 20 cm/s, however, exhibited steady flight ($F_{3,28} = 5.90$, $P = 0.003$) than those flying at the higher speed of 32 cm/s (Fig. 3).

The direction (place) of landing was significantly affected by wind speed. Most beetles (60%) flying at 20 cm/s landed upwind compared to none (0%) at 32 cm/s ($F_{3,28} = 6.85$, $P = 0.001$). The proportion landing downwind was higher at 32 cm/s than at 20 or 0 cm/s ($F_{3,28} = 5.47$, $P = 0.004$). The proportion of beetles landing in the middle part of the tunnel was significantly higher in still air (0 cm/s) than at other wind speeds ($F_{3,28} = 11.50$, $P = 0.0001$) (Fig. 4).

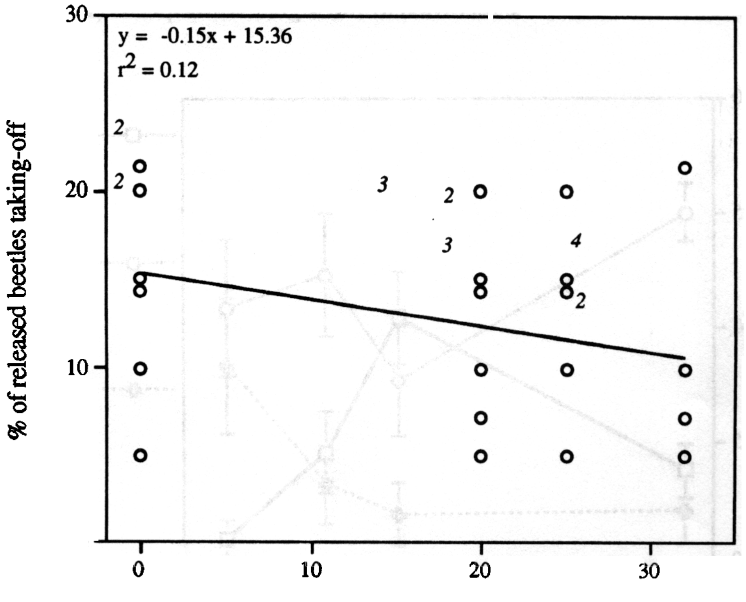

Fig. 1. Effect of wind speed on flight initiation by *P. truncatus*. Figure shows mean % take-off by beetles released for 5 min at each wind speed. A total of 148 beetles were released at each wind speed in 8 replicates. Significant linear model ($P = 0.04$). Numbers in italic show the number of points too close to be separately identified.

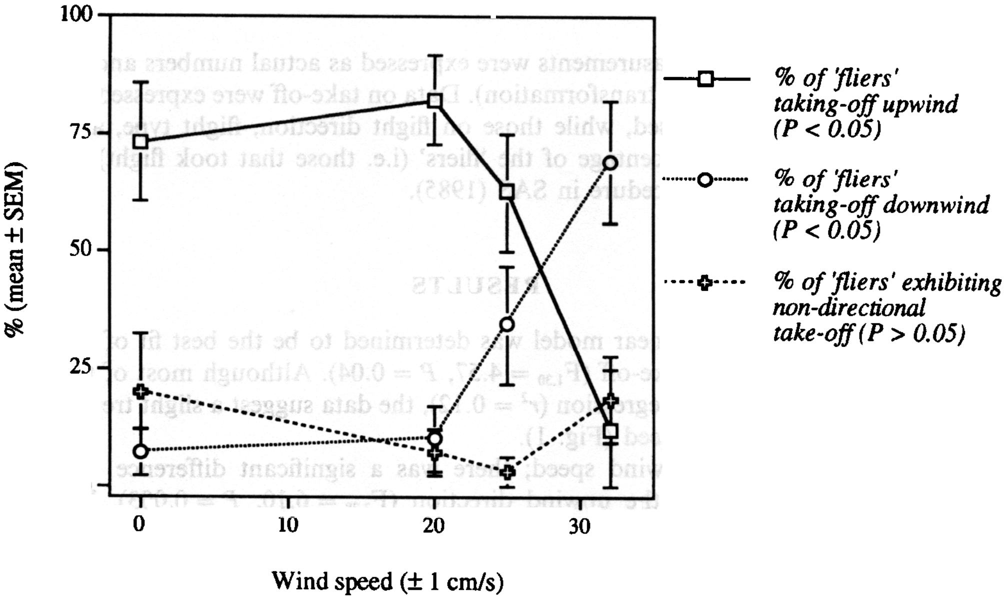

Fig. 2. Effect of wind speed on direction of take-off by *P. truncatus*. Figure shows mean % of flying beetles heading in each direction. The three classifications of direction of take-off are not independent although a beetle could only fall into one of the three categories.

Total flight time (TFT) was not significantly affected by wind speed ($F_{3,68} = 2.51$, $P = 0.07$) although the data suggest that beetles tended to fly longer at 20 cm/s than at 32 cm/s (Fig. 5).

DISCUSSION

The results of this experiment uncover behavioural flight responses of *P. truncatus* to different wind speeds. The data show that although *P. truncatus* is capable of initiating flight at all tested wind speeds, the frequency of flight initiation is highest under still air or at low wind speed conditions: slightly fewer take-offs were recorded at the higher wind speeds (Fig. 1). Flight initiation

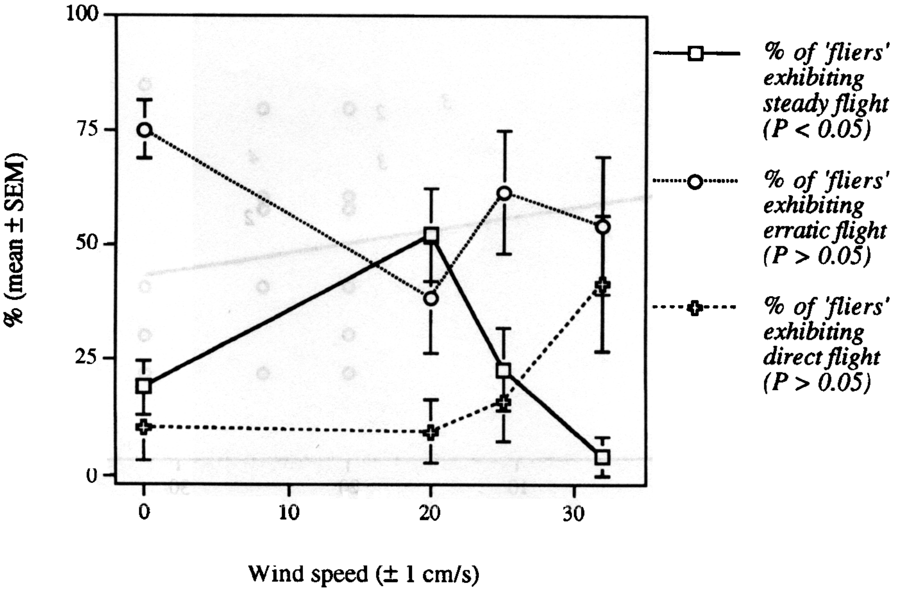

Fig. 3. Effect of wind speed on the type of flight exhibited by *P. truncatus*. Figure shows mean % of flying beetles exhibiting each type of flight. The three flight-type classifications are not independent although a beetle could only fall into one of the three categories.

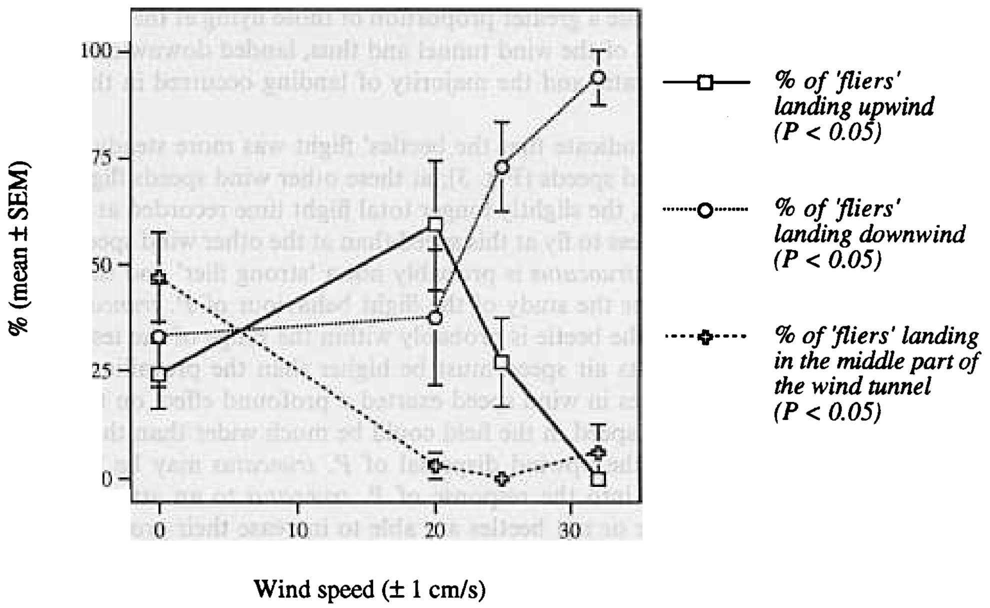

Fig. 4. Effect of wind speed on direction of landing by flying *P. truncatus*. Figure shows mean % of flying beetles landing in each direction. The three classifications of direction of landing are not independent although a beetle could only fall into one of the three categories.

by *P. truncatus* has also been recorded in still air in incubators (Fadamiro and Wyatt, 1995) and it suggests that wind is not necessary for take-off in the species, as was also reported for a scolytid beetle *Trypodendron lineatum* (Salom and McLean, 1991).

Most of the beetles that took-off in still air or at 20 cm/s flew upwind whereas at the higher wind speeds flight direction shifted to downwind (Fig. 2). This is hardly surprising since it is wasteful for an insect to expend energy flying against a strong wind except of course in response to an attractive source, which was not investigated in this study. *Trypodendron lineatum* has nevertheless been reported to fly downwind at a wind speed as low as 30 cm/s even in the presence of an attractant (Salom and McLean, 1991). In the present study, *P. truncatus* flew upwind in wind possibly because they were released facing upwind on the platform. The majority of the beetles

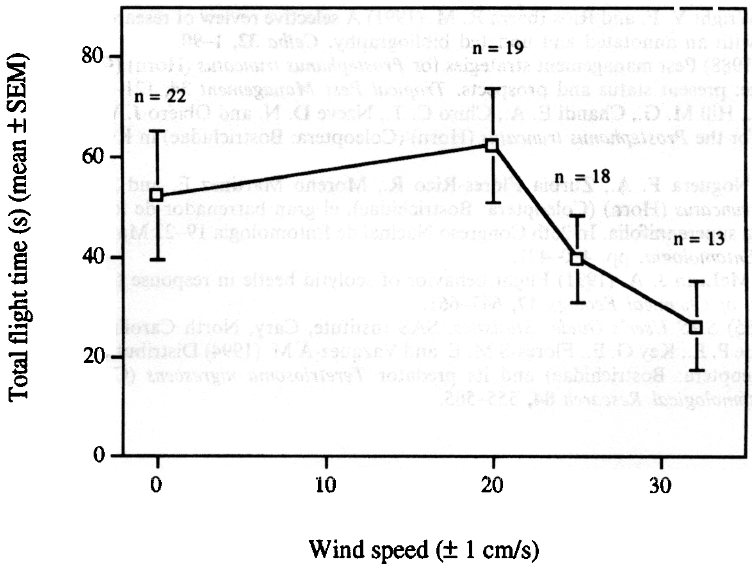

Fig. 5. Effect of wind speed on flight duration of *P. truncatus*. Figure shows mean total flight in seconds. Numbers of flying beetles (*n*) observed for the different treatments were unequal ($P = 0.07$).

flying at 20 cm/s landed upwind while a greater proportion of those flying at the higher wind speeds could not traverse the upwind part of the wind tunnel and thus, landed downwind (Fig. 4). In still air, however, flight was mostly erratic and the majority of landing occurred in the middle or the downwind part of the tunnel.

The data on overall flight type indicate that the beetles' flight was more steady and directional at 20 cm/s than at other tested wind speeds (Fig. 3); at these other wind speeds flights were mostly erratic and unsteady. Furthermore, the slightly longer total flight time recorded at 20 cm/s (Fig. 5) probably indicates a greater readiness to fly at this speed than at the other wind speeds investigated.

All these results suggest that *P. truncatus* is probably not a 'strong flier' and that a wind speed of no more than 20 cm/s is best for the study of the flight behaviour of *P. truncatus*. The results also indicate that the air speed of the beetle is probably within the range of the tested wind speeds since for an insect to fly upwind its air speed must be higher than the prevailing wind speed. It is surprising that the small increases in wind speed exerted a profound effect on the beetles' flight behaviour since the range of wind speed in the field could be much wider than those tested in this study. These results suggest that the upwind dispersal of *P. truncatus* may be limited in windy conditions. Further investigations into the response of *P. truncatus* to an attractant at different wind speeds should reveal whether or not beetles are able to increase their ground speed in order to make upwind progress to the source.

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