Journal of Stored Products Research 76 (2018) 43–50

Contents lists available at ScienceDirect

Journal of Stored Products Research

journal homepage: www.elsevier.com/locate/jspr

Flight of three major insect pests of stored grain in the monsoonal tropics of India, by latitude, season and habitat

T. Sonai Rajan [a], V. Muralitharan [a], G.J. Daglish [b], S. Mohankumar [c], M.A. Rafter [d], S. Chandrasekaran [a], S. Mohan [a], D. Vimal [e], Chitra Srivastava [e], M. Loganathan [f], G.H. Walter [d, *]

[a] *Department of Agricultural Entomology, Centre for Plant Protection Studies, Tamil Nadu Agricultural University, Coimbatore – 03, India*
[b] *Department of Agriculture and Fisheries, EcoSciences Precinct, GPO Box 267, Brisbane, Queensland 4001, Australia*
[c] *Department of Plant Biotechnology, Centre for Plant Molecular Biology and Biotechnology, Tamil Nadu Agricultural University, Coimbatore – 03, India*
[d] *School of Biological Sciences, The University of Queensland, St Lucia, Brisbane, Queensland 4072, Australia*
[e] *Division of Entomology, Indian Agricultural Research Institute, Pusa Campus, New Delhi – 12, India*
[f] *Department of Primary Processing, Storage and Handling, Indian Institute of Food Processing Technology, Thanjavur – 05, India*

A R T I C L E I N F O

Article history:
Received 3 October 2017
Received in revised form
15 December 2017
Accepted 15 December 2017

Keywords:
Seasonal flight pattern
Tribolium castaneum
Rhyzopertha dominica
Sitophilus oryzae
India
Pheromone traps

A B S T R A C T

The timing, extent and landscape coverage of the flight of stored product insect pests could influence their ecology differentially across climatic zones. We therefore assessed the seasonal flight patterns of *Tribolium castaneum* (Herbst), *Rhyzopertha dominica* (F.) and *Sitophilus oryzae* (L.) monthly, for 18 months, in three habitats (around bulk grain storage, in cropping habitats, and in mixed orchard habitats) in southern India (Coimbatore and Thanjavur) and northern India (New Delhi) using pheromone traps. We tested for species-specificity in their seasonal flight patterns as well as regional variation. Vastly more beetles were trapped near bulk grain storages than in cropping and orchard habitats. In both southern and northern India, *T. castaneum* was most numerous, with numbers much higher in southern India. *Rhyzopertha dominica* was more commonly trapped in New Delhi, a wheat producing region, than in the rice producing south. The numbers of *T. castaneum* trapped across time and geographical location varied significantly, with peak flight activity during the post-monsoon period (October). By contrast, *R. dominica* in New Delhi peaked once during summer (May) around bulk storage but tended to be more consistent (but far less numerous) in habitats away from storage. Only a few *S. oryzae* were caught in pheromone traps. The mean trap catches of *T. castaneum* in Thanjavur and New Delhi showed significant positive correlations with minimum temperatures, whereas those of *R. dominica* in New Delhi were significantly correlated with maximum temperatures. The patterns recorded are consistent with results recorded on other continents, but temperature thresholds for flight need to be examined in this context. A major difference was that beetles, especially *T. castaneum*, were captured far less frequently in traps away from storage in India than in Australia, a pattern that needs to be confirmed before a biological basis for it is sought.

1. Introduction

The role of movement in the ecology of insect pests of stored products is difficult to interpret because these organisms are moved in significant numbers with the bulk transport of commodities, and most are also able to fly. Disentangling the relative contributions of these processes to the rate of infestation of bulk stored grain is in its infancy and is, despite its relevance to the environmentally sound management of these pests and the effective management of phosphine resistance, currently a major challenge in understanding the ecology of these species. Each mode of pest movement has to be understood in its own right before their relative contributions can be assessed (Nopsa et al., 2015). The different beetle species involved are known for their differential flight propensities and abilities, but even these are not yet well understood, and the depth of understanding of the movement of

* Corresponding author. Present/Permanent Address: School of Biological Sciences, The University of Queensland, Brisbane, Queensland 4072, Australia.
E-mail address: g.walter@uq.edu.au (G.H. Walter).

https://doi.org/10.1016/j.jspr.2017.12.005
0022-474X/

pest grain beetles varies with species and region.

Tribolium castaneum (Herbst) is believed to generate new infestations in bulk grain storage primarily through the anthropogenic transport of commodities (Good, 1933; White, 1981; Campbell and Arbogast, 2004; Drury et al., 2009; Campbell et al., 2010). This view has presumably been nurtured by those who have used this species as a "model organism" in ecology, as insects that do not fly (as explained by Ridley et al. (2011)). Recent investigations of the spatio-temporal pattern of *T. castaneum* movement across subtropical cropping regions of eastern Australia (a site in which movement of grain between storages is limited) have found that these beetles are routinely captured in flight (throughout the year), even at distances >1 km from bulk-stored grain (Ridley et al., 2011; Daglish et al., 2017). These trapping data, together with population genetic analyses on the trapped insects, indicate that the beetles fly often enough and far enough to render the entire population genetically homogenous over relatively large areas (7000 km^2) (Ridley et al., 2011).

Rhyzopertha dominica (F.), by contrast, is characterized as a strong flier that can be intercepted in flight at substantial distances from grain storage (Cogburn, 1988; Edde et al., 2006; Ridley et al., 2016), and this species has been demonstrated to disperse across diverse environments (Mahroof et al., 2010). Studies of *R. dominica* dispersal have been concentrated in temperate and subtropical areas of the United States (Leos-Martinez et al., 1986; Throne and Cline, 1994; Edde et al., 2006; Toews et al., 2006 Mahroof et al., 2010), Canada (Fields et al., 1993) and Australia (Sinclair and Haddrell, 1985; Wright and Morton, 1995; Ridley et al., 2016). Most of these studies have found that *R. dominica* is active only in summer in temperate areas (Sinclair and Haddrell, 1985; Throne and Cline, 1994), but also in small numbers even in the coldest months in subtropical areas (Ridley et al., 2016; Daglish et al., 2017).

Sitophilus oryzae (L.) has been captured in flight in the vicinity of stored grain in several countries, in both passive traps and traps baited with aggregation pheromone lures (Sinclair and Haddrell, 1985; Throne and Cline, 1989; Likhayo and Hodges, 2000). Laboratory studies on this species have evidently revealed variation across populations in their propensity for flight (Grenier et al., 1994; Cox et al., 2007), and only those strains infected with the endosymbiont *Wollbachia* seem able to fly in the laboratory (Grenier et al., 1994). Despite evidence of flight by *S. oryzae* in the vicinity of stored grain, only limited information is available on the potential for more extensive flights by this species. Specifically, Sinclair and Haddrell (1985) captured small numbers of beetles in farm fields using sticky traps and with a trap mounted on a moving vehicle.

Spatio-temporal data on the flight of storage pests in a heterogeneous agricultural landscape in a tropical monsoonal climate, such as that of India, are not available. We therefore conducted a monthly trapping survey, over 18 months, to determine the movement of *T. castaneum, R. dominica* and *S. oryzae* within various habitats close to and at a distance from bulk grain storage in two different climatic regions of India. India stores (and moves) vast quantities of food grains in bulk throughout the year, particularly rice and wheat, and significant post-harvest grain losses caused by insect pests have been reported. Also, households store small quantities of grain for consumption, and our trapping sites were essentially urban (at bulk storage depots) or peri-urban (with respect to the other habitats).

Based on earlier reports on pheromone trapping of flying beetle pests of stored grain (Ridley et al., 2011, 2016; Daglish et al., 2017) we predicted that trap catches of *T. castaneum* and *R. dominica* would be much higher near bulk storage in India than those captured near bulk stores in Australia. We also anticipated that trap catches in habitats away from bulk storage (in cropping and mixed orchard habitats) would be disproportionately higher (relative to results from bulk storage sites) than in Australia. These expectations relate to our initial observations in India, where vast numbers of beetles can be readily observed each day in the late afternoon, crawling on the surfaces of bag stacks and taking to flight. In Australia, by contrast, *T. castaneum* and *R. dominica* beetles can be observed flying from bulk grain storage and can be trapped near storage, but numbers tend to be low and on some days no beetles take flight (Ridley et al., 2011, 2016; Rafter et al., 2015, 2018). We also anticipated that the flight of these beetles would be less seasonal in southern India than it is in Australia, where temperatures differ more strongly across seasons. In northern India, however, we anticipated strong seasonality in flight activity because of the wider seasonal range in temperatures there than in southern India.

2. Materials and methods

2.1. Study locations

Trapping was undertaken at two locations in southern India [at Coimbatore (11.0183° N, 76.9725° E) and Thanjavur (10.7825° N, 79.1313° E), both in Tamil Nadu] and one in northern India [at New Delhi (28.6139° N, 77.2089° E)]. We deployed multidirectional flight traps baited with species-specific aggregation pheromone lures. The distance between the two southern locations is about 250 km, and 1800 km between New Delhi and each of the southern locations. Tamil Nadu is close to the equator and tends to be relatively warm and stable climatically, whereas a wide seasonal range of temperatures typifies New Delhi (Fig. 1). A monsoon season occurs in both northern and southern India. The southwest monsoon affects the entire country from June to September and the northeast monsoon brings rain to Tamil Nadu from October to December (Fig. 1). Rice is the main cereal crop in southern India, whereas wheat is the main crop in northern India. Despite this, rice and wheat are routinely transported in bulk across the whole of India, and is bulk stored in areas where it is not grown.

2.2. Sampling

Thirty traps were set at each of the three geographical localities, with 10 traps placed at each of three habitats within each locality. The habitats included areas around bulk grain storage (in warehouses called godowns, with grain held in 50 kg jute sacks), cropping (rice or wheat fields) and mixed orchard (fruit and vegetable crops) habitats. These three habitats within each locality were separated by 5, 3 and 8 km (Coimbatore), 10, 11 and 14 km (Thanjavur), and 1.5, 2.5 and 1.5 km (New Delhi) from one another. Each trap was suspended 1.5 m from the ground on a steel pole and was at least 30 m from any other trap. The traps were custom made of galvanized iron for the study (Melwin Engineering Pvt. Ltd., Coimbatore) (Fig. 2).

Each trap was baited with three species-specific pheromone lures, one each for *T. castaneum, R. dominica* and *S. oryzae* (Insects Limited Inc., Westfield, IN, USA). Traps were set for the first 7 days of each month, starting from September 2013 and continuing until February 2015 for all three locations, except for the trapping period in November 2014 at Coimbatore, when no trapping could be conducted. New pheromone lures were used for each trapping period. At the end of each week's trapping, the numbers of *T. castaneum*, *R. dominica* and *S. oryzae* adults were counted and sexed. Fifty beetles of each species (if fewer than this were trapped, then all beetles in the sample) from randomly selected traps (one from each habitat at all three locations) were sexed each month. Male and female adults of *T. castaneum* were identified by the presence (male) or absence (female) of a sub-basal setiferous