Madras Agric. J., 103 (4-6): 154-158, June 2016
https://doi.org/10.29321/MAJ.10.001010

Studies on Spatial Flight Pattern and Movement of Three Stored Grain Insect Pests in Storage Godown

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Investigations were carried out to assess the spatial flight pattern and movement of three stored grain insect pests in storage godown using sticky traps. Significant variations of *Tribolium castaneum* (Herbst) trap catches were registered on different height and trapping periods. The traps placed at a height of 18 feet recorded the highest mean trap catches of *T. castaneum* (341.3 / trap) followed by 15 feet height (202 / trap) and catches between 6 PM – 10 AM were the highest mean trap catches of *T. castaneum,* which ranged from 73.7 to 341.3. Whereas, 4 PM – 6 PM registered 46.3 to 195.7 numbers per trap. The maximum mean trap catches of *Cryptolestes ferrugineus* (Stephens) was observed at a height of 3 feet from the ground level and ranged from 1.7 to 12.0 numbers per trap for different trapping period. Among the trapping period, the period between 4PM – 6PM recorded the maximum mean trap catches (12 / trap). There were no significant differences of mean trap catches of *Ephestia cautella* (Walker) on different height intervals and trapping period. Very low number of *E. cautela* was trapped throughout the study period and the mean trap catches ranged from 0.3 to 2.0 per trap. The trap placed at a height of 18 feet and late evening hours of 6 PM to 10 AM accounted for the maximum mean trap catches (2.0 / trap). The independent variable temperature exerted a significant influence on movement of *T. castaneum* and *C. ferrugineus* and showed that one degree rise in temperature could reduce the trap catches by 3.15 and 4.41 numbers, respectively. However, the relative humidity showed significant influence on movement of *T. castaneum* and *E. cautella* and revealed that one per cent of relative humidity could increase the trap catches by 3.29 and 2.99 numbers, respectively.

Key words: Spatial flight pattern, Storage pests, *Tribolium castaneum*, *Cryptolestes ferrugineus*, *Ephestia cautella*, Sticky trap, Storage godown

There are 15 to 20 species of insect pests associated with Indian stored grain environments and play a major role in deterioration of food grains and cause post-harvest losses (quantitative and qualitative losses) up to 5 to 10 per cent (Cao *et al.*, 2002). Because of potential economic damage caused by those insect pests, there is an urgent need for better understanding of not only the behavior but also, their ecology in heterogeneous landscapes and within the storage structures. Investigating the ecology of stored grain insect pests may help to identify the crucial factor, which is responsible for the movement of stored grain insect pests. The monitoring system is the base for measuring the pattern and movement of stored grain insect pests and provides not only the type and number of insect pests present, but also detects the variations in pest populations over the period and location of infestations and routes of entry (Burkholder, 1990). The monitoring of stored grain insect pests includes the direct sampling of food grains using visual observation and indirect sampling of the insects dispersing among resource area using tools such as pheromone or sticky traps. Direct sampling of food grain is often destructive and difficult or too expensive as food grains are stored in bags, while indirect sampling is advantageous due to minimal requirements for time and man power, increased sensitivity (Barak and Harein, 1982; Lippert and Hagstrum, 1987) and continuous sampling over an extended period of time (Lippert and Hagstrum, 1987; Vela-Coiffer *et al*., 1997). Sticky traps or traps with gummy substances offer one of the best indirect sampling tools for monitoring the flying stored grain insect pests (Semeao *et al*., 2013; Arthur *et al.*, 2014) within the storage godown.

A number of studies have been reported to address the seasonal flight pattern and movement of stored grain insect pests in heterogeneous landscapes particularly, the farm fields (Fields *et al*., 1993), bulk grain storage structures (Brenner *et al*., 1998; Arbogast *et al*., 2003), food processing facilities (Rees, 1999; Campbell *et al*., 2002; Semeao *et al*., 2013), flour mills (Doud and Phillips, 2000; Campbell and Arbogast, 2004), retail stores (Arbogast *et al*., 2000), outside the storage godown and different geographical habitats (Campbell *et al*., 2002). However, the spatial flight pattern and movement of stored grain insect pests within the storage godowns of Indian storage environment is lacking. Monitoring the flight pattern and movement of stored grain insect

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pests within the storage structures or godowns would help to assess the spatial extent of populations, the potential for colonization of stored grain insect pests and development of decision supporting tools for evolving the effective integrated pest management (IPM) strategies. In addition, it is also possible to evaluate the effectiveness of management strategies such as fumigation by comparing the trends in captures before and after the implementation of management strategy (Philipps *et al*., 2000; Campbell and Arbogast, 2004; Campbell *et al*., 2010). Hence, the present study was focused to assess the flight pattern and movement of stored grain insect pests in storage godown.

Materials and Methods

The flight activity and movement of stored grain insect pests were monitored at different heights and trapping periods in Food Corporation of India (FCI), Coimbatore, Tamil Nadu by using sticky intercept traps. Sticky intercept trap was designed by using acrylic sheet with the dimension of 60.7 cm length and 48.4 cm width. The same size of polythene sheets was smeared with sticky substances (multipurpose grease) and subsequently the polythene sheets were tagged with the acrylic sheet by using bulldog clips (48mm). Six numbers of sticky traps were suspended in between the bag stacks at six different heights from 3 feet to 18 feet starting from ground level to the above bag stack or headspace in the storage godown. A period of 24 h was chosen to assess the flight pattern and movement of stored grain insect pests, because the flight activity of grain insect pests may vary according to the time of day (Leos-Martinez *et al.,* 1986). The sampling of trapped insects was done at 2 hrs intervals from 10 AM to 6 PM and 6 PM to 10 AM. At the end of each trapping period the samples were separated and the number in each species was counted and recorded. The abiotic factors *viz*., temperature and relative humidity were recorded within the storage godown using hand held thermometer to assess the influence of abiotic factors on spatial flight pattern and movement of stored grain insect pests.

The data obtained were subjected to square root (X+0.5) transformation and the analysis of variance for two factors was carried out using AGDATA and AGRES and the means were separated by least significant difference (LSD) available in the package. The linear regression analysis for weather factors were carried out using Statistical Package of Social Sciences (SPSS), ver.16.00 SPSS Inc., USA (Levesque, 2007).

Results and Discussion

Flight pattern and movement of stored grain insect pest was studied by using sticky traps within the storage godown. Several stored grain insect pests were trapped at different heights and trapping periods. Among them, the red flour beetle, *Tribolium castaneum* (Herbst) (Tenebrionidae; Coleoptera), rusty grain beetle, *Cryptolestes ferrugineus* (Stephens) (Cucujidae; Coleoptera) and Almond moth, *Ephestia cautella* (Walker) (Pyralidae; Lepidoptera) were consistently trapped on different heights and trapping periods.

Significant variations of *T. castaneum* trap catches were recorded on different heights and trapping periods. Among the height intervals, the traps that were placed at a height of 18 feet (head space area) recorded the higher mean trap catches (341.3 / trap) followed by 15 feet height (202.0 /trap). The traps placed at a height of 6 and 9 feet registered very less number of insects (Table 1). This showed that red flour beetles were strong fliers and preferred to move towards head space rather than downward comparision trapping periods indicated that the period between 6 PM – 10 AM had the highest mean trap catches of *T. castaneum* which ranged from 73.7 to 341.3 numbers per trap at different heights followed by 4 PM to 6 PM. This ranged from 46.3 to 195.7 numbers per trap. During 10 AM to 12 PM very less number of T. *castaneum* was observed, which showed that the late evening hours was the desirable time for the initiation of flight for *T. castaneum*. The maximum mean trap catches of *C. ferrugineus* was observed at a height of 3 feet from base and the mean trap catches ranged from 1.7 to 12.0 numbers per trap at different trapping periods (Table 1). However, the trap placed at a height of 12, 15 and 18 feet recorded very less mean trap catches of *C. ferrugineus*. Among the trapping periods, the time between 4PM to 6PM recorded the highest mean trap catches (12.0 / traps). This showed that the rusty grain beetles were weak fliers and harbour nearer to the ground. There were no significant differences of mean trap catches of *E. cautella* observed on different heights and trapping periods. Very low number of *E. cautela* was trapped throughout the study period and the mean trap catches ranged from 0.3 to 2.0 per traps. The trap placed at a height of 18 feet and during 6 PM to 10 AM recorded relatively higher mean trap catches of *E. cautella* (2.0 / trap) (Table 1).

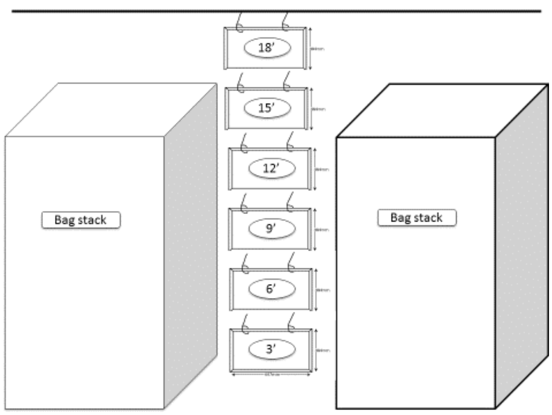

Fig. 1. Sticky traps suspended between the bag stacks at different height level.

The linear regression analysis of trap catches with abiotic factors showed that the temperature had significant variations in trap catches of *T. castaneum* and *C. ferrugineus* by 76.80 and 86.60 per cent (R^2= 0.768 and 0.866), respectively (Table 2). The relative humidity defined the variations in trap catches of *T. castaneum* and *E. cautella* by 78.40 and 75.00 per cent (R^2 = 0.784 and 0.750), respectively (Table 3)

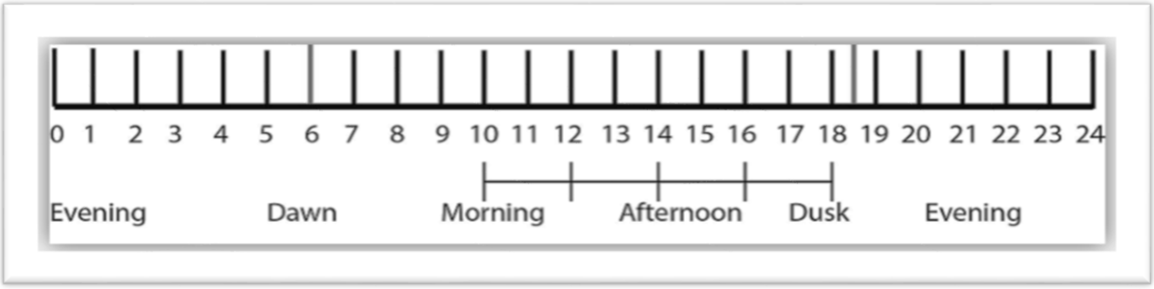

Fig. 2. Scale bar showing the trapping period (0-24 hrs)

within the storage godown. Temperature acted as an independent variable and exerted a significant influence on movement of *T. castaneum* and *C. ferrugineus,* wherein one degree of rise of temperature could reduce the trap catches by 3.15 and 4.41 per traps, respectively (Table 2). Similarly, the relative humidity showed significant influence on movement of *T. castaneum* and *E. cautella* and revealed that one per cent relative humidity could increase the trap catches by 3.29 and 2.99 per traps, respectively for *T. castaneum* and *E. cautella* (Table 3).

Table 1. Mean trap catches of storage insects inside the storage godown at different heights

Insect species	Exposure time	Trapping height intervals (feet)					
		3	6	9	12	15	18
	10 AM-12 PM	5.0 (2.2)^{jk}	4.3 (2.1)^{k}	4.0 (2.0)^{k}	5.7 (2.4)^{jk}	4.0 (2.0)^{k}	8.0 (2.8)^{jk}
	12 PM -2 PM	7.7 (2.8)^{jk}	8.3 (2.9)^{ijk}	7.3 (2.7)^{jk}	9.7 (3.1)^{ijk}	10.7 (3.3)^{ijk}	27.3 (5.2)^{hi}
T. castaneum	2 PM - 4 PM	19.3 (4.4)^{ij}	14.0 (3.7)^{ijk}	18.3 (4.3)^{ijk}	27.7 (5.3)^{hi}	50.7 (7.1)^{gh}	79.3 (8.9)^{efg}
	4 PM - 6 PM	59.7 (7.7)^{g}	46.3 (6.8)^{gh}	63.3 (8.0)^{fg}	70.7 (8.4)^{efg}	138.7 (11.8)^{cd}	195.7 (14.0)^{bc}
	6 PM-10 AM	102.3 (10.1)^{def}	73.7 (8.6)^{efg}	77.7 (8.8)^{efg}	113.7 (10.7)^{de}	202 (14.2)^{b}	341.3 (18.5)^{a}
	10 AM-12 PM	1.7 (1.5)^{ef}	0.7 (1.1)^{fgh}	0.0 (0.7)^{h}	0.0 (0.7)^{h}	0.0 (0.7)^{h}	0.0 (0.7)^{h}
	12 PM -2 PM	3.7 (2.0)^{cd}	1.7 (1.5)^{ef}	1.3 (1.4)^{efg}	0.3 (0.9)^{gh}	0.0 (0.7)^{h}	0.3 (0.9)^{gh}
C. ferrugineus	2 PM - 4 PM	6.7 (2.7)^{b}	2.7 (1.8)^{de}	1.3 (1.4)^{fg}	0.3 (0.9)^{gh}	0.7 (1.1)^{fgh}	0.3 (0.9)^{gh}
	4 PM - 6 PM	12.0 (3.5)^{a}	4.3 (2.2)^{cd}	1.3 (1.4)^{fg}	0.7 (1.1)^{fgh}	0.7 (1.1)^{fgh}	0.7 (1.1)^{fgh}
	6 PM-10 AM	5.3 (2.4)^{bc}	3.3 (2.0)^{cd}	2.7 (1.8)^{de}	0.7 (1.1)^{fgh}	1.0 (1.2)^{fgh}	0.7 (1.1)^{fgh}
	10 AM-12 PM	0.0 (0.7)	0.0 (0.7)	0.7 (1.1)	0.3 (0.9)	0.0 (0.7)	0.0 (0.7)
	12 PM -2 PM	0.0 (0.7)	0.0 (0.7)	0.3 (0.9)	0.3 (0.9)	0.0 (0.7)	0.7 (1.1)
E. cautella	2 PM - 4 PM	0.3 (0.9)	0.0 (0.7)	0.0 (0.7)	0.3 (0.9)	0.3 (0.9)	0.3 (0.9)
	4 PM - 6 PM	0.0 (0.7)	0.0 (0.7)	0.3 (0.9)	0.0 (0.7)	0.0 (0.7)	0.7 (1.1)
	6 PM-10 AM	0.0 (0.7)	1.0 (1.2)	0.7 (1.1)	0.3 (0.9)	1.0 (1.2)	2.0 (1.2)

* Values are mean of three replications; Figures in parentheses represents square root transformation; means in a column followed by superscript letters or not significantly different according to DMRT at P = 0.05%

The results of the present study showed variations in trap catches of three storage pests on different heights and trapping periods and this was in agreement with the earlier report of Campbell *et al.* (2002) and Arbogast *et al.* (2003) who, found that the insects trapped in warehouses tend to be spatially and temporally variable. Similar approaches were tested by Nansen *et al.* (2008) who, monitored the stored grain pests movement in food storage facilities using traps placed for limited period of time in selected areas and found significant variations in beetle trap catches.

Table 2. Linear regression analyses of temperature and movement of storage pests

Insect species	Variable	Reg. Coefficient	Std. error	't' value	't' probability	R^2
T. castaneum	Intercept	2038.71	628.13	3.25	0.05	0.768
	Temperature	-68.38	21.70	-3.15**	0.05	
C. ferrugineus	Intercept	38.84	8.39	4.63	0.02	0.866
	Temperature	-1.28	0.29	-4.41**	0.02	
E. cautella	Intercept	4.64	5.01	0.93	0.42	0.199
	Temperature	-0.15	0.17	-0.86 NS	0.45	

**Significant at 5%; NS – Non significant

The flight activity of *T. castaneum, C. ferrugineus* and *E. cautella* showed strong periodicity. Although the flight activity was reported throughout the study period, the maximum trap catches was observed during dusk (4 PM to 6 PM) and dawn. This suggests that, all these three insects showed crepuscular behaviour in nature. The highest catches observed during 6 PM to 10 AM may be attributed to lengthier exposure time. The present finding was in corroboration with Fadamiro and Wyatt (1995), who had reported that the flight activity of larger grain borer, *Prostephanus truncates* (Horn) peaked at 2-0 hour before darkness i.e., tail end of the photo phase. Similar results were obtained on the closely related beetle *Rhyzopertha dominica* (F.) in the field (Leos-Martinez *et al*., 1986) and laboratory (Barrer *et al.,* 1993). The crepuscular activity may be associated to circadian rhythm, since insects flew more abundantly towards the end of the photo phase in a godown environment.

Table 3. Linear regression analyses of relative humidity (RH) and movement of storage pests

Insect species	Variable	Reg. Coefficient	Std. error	't' value	't' probability	R^2
T. castaneum	Intercept	-930.66	300.96	-3.09	0.05	0.784
	RH	16.31	4.95	3.29**	0.05	
C. ferrugineus	Intercept	-5.88	10.48	-0.56	0.61	0.154
	RH	0.13	0.17	0.74 NS	0.51	
E. cautella	Intercept	-3.84	1.388	-2.763	0.07	0.750
	RH	0.068	0.023	2.99**	0.05	

**Significant at 5%; NS – Non significant

Weather factors (abiotic) affect the physiology and behavioural characters (movement) of insects that may lead to spatial and temporal distribution of insect pests (Kingsolver, 1989). The movement and flight activity of stored grain insect pests are controlled by various environmental factors such as temperature, relative humidity, air pressure, light, wind speed and direction (Speight *et al*., 2008), presence of food source and the physical environment. Weather factors also alter the movement of insect pests into and within storage facilities (Dowdy and McGaughey, 1994) and potential trap captures (Romero *et al.,* 2009). In the present study, the temperature within the storage godown exerted significant influence on *T. castaneum* trap catches. This was agreed with the earlier report of Throne and Cline (1994) and Cox *et al.* (2007) who, reported that temperature influenced the movement of stored grain. Effect of low relative humidity especially insect pests for a small insect, withless haemolymph volume (Unwin and Corbet, 1991) making water loss and reducing the flight was particularly important. In the present study, there is a trend for reduced catches with increased temperature. In vice-versa, positive relationship was observed between RH and trap catches. This is in line with the findings of Cox *et al.* (2007), who reported that maximum and minimum temperatures influenced the movement of stored grains. Also the present work is in confirmation with Trematterra and Sciaretta (2004), who reported that maximum temperature, rainfall and relative humidity had influenced the variation in trap catches of *T. castaneum*, *R. dominica* and *Sitophilus oryzae* (Linnaeus) in residential and forest area. The result of the present study showed that *T. castaneum*, *C. ferrugineus* and *E. cautella* are spatially and temporally distributed within the storage structures and their flight activity started during late evening hours. This finding could help to monitor the storage pests within the storage structures and also to validate the prophylactic and curative treatments.

Acknowledgement

This study was financially supported by Australia and India Strategic Research Fund (AISRF) project entitled "Ensuring food security: a harnessing science to protect our grain harvest from insect threats", sponsored by Government of India, Department of Science and Technology (DST), India. The authors extend special thanks to all the managers and technical staff of Food Corporation of India, North Coimbatore, Tamil Nadu for helping to conduct the experiment.

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Received after revision: June 21, 2016; Accepted: June 29, 2016