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Use of light traps in a phosphine resistance management strategy for *Tribolium castaneum* in Indian grain storage warehouses

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ABSTRACT

Tribolium castaneum (Herbst) is a cosmopolitan, polyphagous and major secondary pest of processed or damaged food grains. Phosphine fumigation is the sole method to control this pest in Indian grain storage warehouses. Repeated fumigation has resulted in development of several fold resistance to phosphine in *T. castaneum*. In India, a detailed nationwide survey of resistance to phosphine in stored grain insect pests highlighted the presence of phosphine resistant phenotypes in *T. castaneum* at high frequencies of 100%. At present there is no management strategy to combat this resistance problem. The Tamil Nadu Agricultural University Ultra Violet (TNAU UV)- Light trap recommended for management of *T. castaneum* and *Rhizopertha dominica* (Fabricius) in grain storage warehouses. Currently TNAU UV- Light trap technology has been introduced in the Food Corporation of India (FCI) godowns in large scale. Studies were made by analyzing the *Tribolium castaneum* (Herbst) caught in the UV light trap during the post fumigation period in warehouses of the Food Corporation of India, Peelamedu, Coimbatore, Tamil Nadu, India during 2015 for phosphine resistance using a modified FAO method. Bioassays were conducted using two discriminating concentration of phosphine gas, viz. the low concentration (0.03 mg L^{-1}) and high concentration (0.25 mg L^{-1}) over 20 h exposure period. The results revealed that the frequency of phosphine resistance in *T. castaneum* tested at low concentration (0.03 mg L^{-1}) ranged from 87.45 to 100% and at high concentration (0.25 mg L^{-1}), it ranged from 63.84 to 85.39%. The present study reveals that the TNAU UV-Light trap can be used to monitor *T. castaneum* before and after a phosphine fumigation as part of a management strategy for controlling the resistant population of *T. castaneum.*

Key words: Grain storage warehouse, Phosphine resistance management, TNAU UV-light trap, *Tribolium castaneum*

In India, more than 50% of the food grains produced are stored in various situations at rural level and only 5–10% is stored in scientific storage godowns in large scale as a buffer stock by government agencies like FCI (Food Corporation of India), civil supplies corporations and central warehousing corporations. The common method of storage is in gunny bags; bulk handling in silos is not common. Post-harvest grain losses are significant in India, and the annual loss is 20 million tonnes (Basavaraja et al., 2007) and the estimated loss of food grains accounting to more than ₹ 500,000 million (>$8 billion USD) per year (Singh, 2010). Among biotic and abiotic factors that affect grains in storage, insects play a major role in deterioration of food grains causing both quantitative and qualitative losses.

Tribolium castaneum (Herbst) is a cosmopolitan, polyphagous and major secondary pest of processed or damaged food grains. Phosphine fumigation is the sole method to control this pest in Indian grain storage warehouses, as it is relatively low-priced, easy to apply, residue-free and does not affect the viability of seeds. However, heavy and indiscriminate use of phosphine over the last few decades resulted in development of several fold resistance to phosphine in *T. castaneum*. In India, a detailed nationwide survey of resistance

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to phosphine in stored grain insect pests indicated the presence of phosphine resistant phenotypes in *T. castaneum* at high frequencies of 100% (Rajendran, 1999). Raghavendra (2009) reported that *T. castaneum* collected from 14 TNCSC godowns of Tamil Nadu showed phosphine resistance ranged from 6.67 to 71.67%. Sivakumar (2009) revealed that, resistance of *T. castaneum* to phosphine was high in populations from Madurai (70.21%), Ramanathapuram (65.96%), Coimbatore (61.70%), Cuddalore (59.57%) and Salem (53.19%) of Tamil Nadu, India. Resistance to phosphine poses threat to effective control of this pest. SonaiRajan (2015) reported that the frequency of phosphine resistance in *T. castaneum* tested at low concentration (0.03 mg L^{-1}) ranged from 40.29 to 100% in Tamil Nadu; 71.40 to 93.40% in Kerala and 73.99 to 100% in Andhra Pradesh populations, whereas at high concentration (0.25 mg L^{-1}), the frequency of phosphine resistance ranged from 25.84 to 100, 67.79 to 85.39 and 45.55 to 100% in Tamil Nadu, Kerala and Andhra Pradesh respectively.

Light traps have been widely used for many years to attract stored product insects. Stermer (1959, 1966) showed that majority of stored produce insects were attracted to light of wavelength between 280 and 600 nm. TNAU UV- Light trap has been recommended for management of *T. castaneum* (Herbst) and *R.dominica* (Fabricius) in grain storage warehouses (Mohan et al., 1994). They also suggested that a 4W UV light (peak emission 250 nm) trap set at 1.5 m aboveground level in the alleyways and corners of a rice warehouse will show maximum attraction of *R. dominica.*

Trapping methods are more sensitive than grain samples, so infestation is often detected earlier with traps than with spear sampling or sieving (Reedet al., 2001).Trapping of the resistant beetles emerging after fumigation by using UV light traps may help in effective management of phosphine resistance. Hence the present study was carried out to assess the role of TNAU UV-Light traps in phosphine resistance management of *T. castaneum* in grain storage warehouses.

MATERIALS AND METHODS

The TNAU-UV light trap (M/s Melwin Engineering, Coimbatore is a multidirectional trap with four baffles and mainly consists of an ultra-violet source (4W germicidal lamp). The UV lamp of 20 cm long produces ultra-violet rays of peak emission around 250 nanometer. The light is fitted vertically at the centre of the baffles raised over a steel funnel of 310 mm diameter at the top and 35 mm diameter at the bottom. The bottom end of the funnel is attached with a transparent plastic container for collecting the trapped insects. To hang the unit at desired points, a hook is provided at the top of the trap. The unit is also provided with a tripod stand (Mohan et al., 1994).

Studies were conducted at grain storage warehouses (60 m × 20 m × 6 m) of Food Corporation of India, Peelamedu, Coimbatore, Tamil Nadu, India using TNAU- UV Light Trap to test its role in resistance management in *T. castaneum*. Four UV light traps were deployed inside the warehouse at 1.5 m aboveground level, near the corners of the two warehouses. The trap was operated during night hours (18:00 to 06:00 h). Observations were recorded on the adult beetle strapped per trap on daily basis continuously for ten days before and after fumigation. The experiment was conducted during October to December 2015. Cover fumigation of stacks with aluminium phosphide (Celphos) tablets (3g) at three tablets/tonne with 7 days exposure period was done when there was a steady increase in the light trap catch and when adult beetles activity was noticed on the bags.

The adults collected from UV light trap were brought to the Toxicology Laboratory, Department of Agricultural Entomology, Tamil Nadu Agricultural University, Coimbatore, for mass culturing. Mass culturing was done in 2.0 kg plastic container along with 500 g of wheat (*Triticum aestivum* L.) flour + 5% yeast and kept for oviposition at room temperature of 30°C and 60% r.h., to obtain sufficient number of insects for resistance bioassay. The new batch of (next generation) adults was emerged from the culture, with uniform age were used for the phosphine resistance bioassay. Phosphine gas was generated in a gas generation chamber and volume of dessicator was measured by following the procedure as described by Sonai Rajan (2015). The correct phosphine gas volume for injection was determined based on weight by volume basis which was previously described by FAO Method No. 16 (FAO, 1975).

$$d_1(\mu l) = \frac{298 \times x_1\,(mg/l) \times v_1\,(l) \times 22.414 \times 1{,}000 \times 1{,}000 \times 100}{273 \times 1{,}000 \times 33.9977(\text{GMW of phosphine}) \times 86}$$

where d_1 (μl) = volume of phosphine gas required for injection; x_1 (mg/l) = required dose of phosphine in desiccator; v_1 (l) = volume of the desiccator; GMW= gram molecular weight.

The levels of phosphine resistance, whether susceptible, with weak resistance or with strong resistance, was determined for the progeny of trapped insects using a modified FAO method (FAO, 1975). Adult insects of *T. castaneum* were fumigated with

Table 1 Phosphine resistance level in *Tribolium castaneum* collected from UV light traps before and after fumigation with phosphine in Food Corporation of India grain storage warehouses at Peelamedu, Coimbatore, Tamil Nadu, India

Light trap no.	Percent resistance (Mean ± SE)			
	Before fumigation		After fumigation	
	Low concentration (0.03 mg L^{-1})	High concentration (0.25 mg L^{-1})	Low concentration (0.03 mg L^{-1})	High concentration (0.25 mg L^{-1})
Trap 1	91.49 ± 0.25	64.66 ± 0.30	99.43 ± 0.09	75.84±1.76
Trap 2	88.05 ± 0.39	67.79 ± 0.25	87.45± 0.07	82.99 ± 0.77
Trap 3	85.32 ± 0.10	56.38 ± 0.21	100.00 ± 0.00	74.37 ± 0.08
Trap 4	93.40 ± 0.09	60.04 ± 0.12	94.40 ± 0.18	85.39 ± 0.32
Mean	89.57± 0.20	62.22± 0.22	95.32±0.09	79.65±0.73

two discriminating concentration of phosphine gas, viz. the low concentration (0.03 mg L^{-1}) for weak resistance, and high concentration (0.25 mg L^{-1}) for strong resistance, over a 20 h exposure period. The bioassay was performed at room temperature of 30ºC and 60% r.h. Each resistance bioassay test was replicated thrice along with control for each population and 50 adult insects were released per replication. After exposure, the insects were provided with small quantity of culture medium for a week and moved to recovery room. Adult mortality was determined after seven days from the end of the exposure period. The observation on number of insects responding, i.e. insects showing any movements were considered to be alive and others as dead. Mortality response data were calculated using Abbott's formula (Abbott, 1925), to eliminate the influence of mortality in control beetles that were exposed to just clean air, which was not greater than 10% in these experiments. The resistance per cent age was worked out as:

Resistance per cent age (R) = (100-CM) ± SE

where CM = corrected mortality; SE = standard error. Pooled binomial standard error was calculated by using the formula, SE = Stdev / $\sqrt{n}$. The data obtained were analysed statistically by MS-Excel.

RESULTS AND DISCUSSION

The results showed that the mean number of beetles caught per light trap per day during the pre and post fumigation period was 374.6±0.71 and 48.2±0.95 beetles per trap/d, respectively. During the post fumigation period, though the pest population was presumably low from the fumigation, the mean number of beetles caught per trap was 48.2 ± 0.95. This shows that light traps can be effective in mass trapping of *T. castaneum* during post fumigation period in grain storage warehouses. Our results confirm the findings of Mohan et al. (1994), who found that TNAU-UV Light trap was effective in mass trapping of *R. dominica* during post fumigation periods in rice warehouse. Stermer (1959, 1966) showed that majority of stored produce insects were attracted to light of wavelength between 280 and 600 nm.

The phosphine bioassay results showed that the populations collected from UV-light traps at 10 days before and after fumigation showed slight difference in the frequency of resistance (Table 1). The frequency of resistance in beetles captured from pre-fumigated populations tested at low concentration (0.03 mg L^{-1}) ranged from 85.32 ± 0.10 to 93.40 ± 0.09%, whereas at high concentration (0.25 mg L^{-1}) ranged from 56.38 ± 0.21 and 67.79 ± 0.25%. Beetles from the post fumigation populations, when tested at low concentration (0.03 mg L^{-1}) and high concentration (0.25 mg L^{-1}), showed phosphine resistance % ranged from 87.45± 0.07 to 100.00% and 74.37 ± 0.08 to 85.39 ± 0.32%, respectively (Table 1). The present results are in concurrence with Sonai Rajan et al. (2015) who reported high frequency of phosphine resistance in *T. castaneum* populations from three major south Indian states, tested at low and high concentrations. The high frequency of phosphine resistance in the post fumigation population may be due to less number of susceptible individuals compared to pre fumigation population.

CONCLUSION

The TNAU UV-light traps were found to be efficient in mass trapping of *Tribolium castaneum* both in pre- and post-fumigation periods. Further, the frequency of phosphine resistance was higher in *T. castaneum* populations collected from UV light trap after fumigation than those collected before fumigation. The present results revealed that UV light traps can capture phosphine resistant *T. castaneum* populations during the post fumigation period in grain storage warehouses. Hence TNAU UV- light trap can be recommended as one of the tools to use in a phosphine resistance management strategy for *T. castaneum* in grain storage warehouses.

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