Available online at http://www.journalijdr.com

IJDR

ISSN: 2230-9926

International Journal of Development Research
Vol. 08, Issue, 04, pp.19781-19789, April, 2018

ORIGINAL RESEARCH ARTICLE OPEN ACCESS

EVALUATION OF DIFFERENT MONITORING TRAPS AGAINST STORED GRAINS INSECT PESTS IN RICE PROCESSING UNITS OF THE PUNJAB PROVINCE, PAKISTAN

Babar Bajwa, *Sabyan Faris Honey, Muhammad Sohail Mazhar and Ayesha Riaz

Centre of Agriculture and Biosciences International (CABI), Regional Centre (Central and West Asia), Rawalpindi, Pakistan

ARTICLE INFO

Article History:

Received 17th January, 2018
Received in revised form
17th February, 2018
Accepted 18th March, 2018
Published online 30th April, 2018

Key Words:

Khapra beetle, monitoring, rice, Storage conditions, traps.

ABSTRACT

During past few years, continuous detection of khapra beetle was reported in rice consignments shipped from Pakistan to USA and Mexico. It triggered partner countries to enforce export restrictions on Pakistani processed rice causing millions of dollars loss to the country. Finally, it accelerated exporters to streamline this problem and to find the source of interception in rice supply chain of the country. This study was designed in collaboration with Rice Exporters Association of Pakistan (REAP) to monitor the activity of khapra beetle along with other insect pests in different rice processing units of the Punjab province. Dome, probe and sticky traps were used for monitoring storage pests both indoor and outdoor of storage facilities. Based on results, Probe traps were found significantly effective in capturing khapra beetle in all localities. Population of khapra beetle was found significantly low and negligible in many cases with respect to other stored grains insects. In case of other insects, *Tribolium castaneum* and Psocids contributed maximum insect count in all traps. Moreover, indoor vicinities were found significantly high accommodating places for stored grains insect pests as compared to outdoor vicinities in all rice processing units.

Citation: Babar Bajwa, Sabyan Faris Honey, Muhammad Sohail Mazhar and Ayesha Riaz, 2018. "Evaluation of different monitoring traps against stored grains insect pests in rice processing units of the punjab province, Pakistan", *International Journal of Development Research*, 8, (04), 19781-19789.

INTRODUCTION

Rice is one of the cash crops of Pakistan and is considered as second staple food after wheat. It contributes about 0.6 percent of the country GDP and about one third of the produce is exported annually. However, decline of 4.9 percent was observed in its cultivated area during 2015-2016 as compared to 2014-2015due to low selling prices of rice on global scale. It resulted in 2.7 percent less production and shifted farmers towards cultivation of fodder and maize crops as alternate to rice. Furthermore, Pakistani Basmati rice is still facing tough competition in world market due to provision of cheap rice from neighboring countries (PES, 2015-2016). Storage of rice is the most common practice in the country. Low standards of handling crop and poor sanitation during storage promote different biotic and abiotic factors that may cause losses to stored product (Howe, 1965).

Corresponding author: **Sabyan Faris Honey,**
Centre of Agriculture and Biosciences International (CABI), Regional Centre (Central and West Asia), Rawalpindi, Pakistan.

Insect pests are considered as one of the main destructive biotic factors under storage conditions where they can cause 5-10% loss in temperate and 20-30% loss in tropical zones (Nakakita, 1998). After harvesting, rice is stored as paddy or polished rice for further processing and export purposes. About thirty species of insect have been reported on stored rice, however only *Tribolium castaneum* (Herbst), *Sitophilus oryzae* L., *Sitotroga cerealella* (Olivier) and *Rhyzopertha dominica* (Fabricius) cause huge losses to rice during storage periods (Agarwal *et al*., 1979; Ebeling, 2002; Lindgren*et al*., 1955; Shafique and Ahmad, 2003). They not only cause direct damage to grain by feeding and contamination with cast skins and feces, but also make the grains dumpy through their rapid respiration mechanism promoting development of microorganism in the product (Hall, 1970; Hubert *et al*., 2004; Smith *et al*., 1971). Besides these, *Trogoderma granarium* has also been reported feeding on stored rice (Ramzan and Chahal, 1986). The infestation of khapra beetle is dependent on storage structures and grain processing units where ample quantity of food material is available. It does not have profound effect on environment but can greatly affect human being through imposing quantitative and qualitative losses to stored food material through its voracious feeding habit. Its larvae have the ability to survive up to 81% over stored rice, where it can consume 3-12 mg of the available food on an average during their larval developmental time (Ismael *et al*., 1988: 1989; Karnavar, 1973). Low intensity of light in storage structures especially in developing countries favors the more utilization of the available food (Sohi, 1986). The World Trade Organization committee on Sanitary and Phytosanitary measures has already imposed restrictions on import of wheat and related grains and cereals where Khapra beetle infestation may be found especially from developing countries including Pakistan (Ahmedani *et al*., 2011). In recent years, *Trogoderma granarium*, primarily known to cause economic damage to stored wheat (Azeem *et al*., 1976; Hameed *et al*., 1989; Baker *et al*., 1991; Mark *et al*., 2010) was detected within rice shipments exported from Pakistan (Reuters, 2013). Many cases were reported, where Khapra beetle detection in rice shipments resulted in their rejection by partner counties. During 2011, Customs and Border Protection Agriculture Specialists (CBP) at New York/New Jersey port, USA found two dead larvae of Khapra beetle in rice consignment shipped from Pakistan. It resulted in re-exportation of the consignment back to Pakistan (Green, 2011). Later in 2013, a shipment of about 1027 bags of rice exported from Pakistan was stopped at port of Chicago USA. Specialists of CBP detected Khapra beetle larvae from the shipment. This shipment was also re-exported to Pakistan (Reuters, 2013). During consecutive year in 2014, dead khapra beetles were again detected in a rice shipment of 43000 pound at port of Baltimore, Maryland, USA. Along with USA, Mexico became a new market for rice export from Pakistan during early 2013. But Mexico found khapra beetle from a rice shipment of 3000MT coming from Pakistan and removed Pakistan from list of eligible importers (Anonymous, 2014). Continuous rejection of rice consignments between 2011-2014 estimating millions of dollars compelled Pakistani exporters to eliminate this pest from rice supply chain of the country. Furthermore, stiff competition in international rice market, drove researchers and exporters to find out an appropriate management tactic to handle this notorious pest in Pakistan. These facts highlighted the importance to monitor the activity of this pest in rice under storage conditions. An effective monitoring approach provides a baseline for achieving successful integrated pest management program against any pest. This provides information about insect phenology and its association with its food during successive months under given circumstances (Burkholder, 1990). For monitoring of stored grains insect pests, different types of pheromones, lures and traps were designed and are commercially available (Vick *et al*., 1990; Phillips *et al*., 2000; Mullen and Dowdy, 2001). The aim of this study was to monitor the activity of khapra beetle and other insects in rice processing units of Hafizabad, Kamoke and Gujranwala within Punjab province, Pakistan to provide the status of these notorious pests under storage structures of rice processing units, from where rice is exported to partner countries.

MATERIALS AND METHODS

Experimental Unit

Three localities namely Gujranwala, Hafizabad and Kamoke were selected based on having major rice processing units in the country. In each locality, three rice processing units were selected where rice is being stored in their warehouse for further processing and exporting to other countries. In each rice processing unit, three types of traps namely Dome, Probe and Sticky traps were fixed inside, while Dome and Sticky traps were installed outside of the warehouses. Each trap was replicated thrice inside and outside warehouse in each processing unit to capture the insect activity. Traps were monitored for *Trogoderma granarium* and other insects like *Oryzaephilus surinamensis, Plodia interpunctella,* Psocids, *Sitophylus oryzae, Tribolium castaneum* and Hymenopterous wasps. Monitoring data was recorded on monthly basis. Traps were replenished after each data recording

Monitoring traps

Dome trap

It consists of trap/catch reservoirs (4.5 inch diameter), dome covers, pheromone lures, absorbent pads and oil based food (kairomone) attractant container. This monitoring trap is used specifically for monitoring or capturing of larval and adult stages of khapra beetle within storage structures. For monitoring purposes, these traps were placed on the floor near stored rice jute bags in warehouse.

Probe trap

In this study, STORGARD WB Probe II traps were used to monitor the activity of beetles within rice bags. It consists of a long and perforated plastic tube designed for easy insertion into grain mass. The tip of 17 – inch probe is the reservoir for insect collection, identification and counting.

Sticky trap

These consist of sticky cards used for monitoring flying insects in storage structures. These were placed against walls for flying insects. Their dimension includes 6 inches width and 4.5 inches diameter. A specialized lure for attraction of flying insects was placed inside the sticky traps for monitoring purposes.

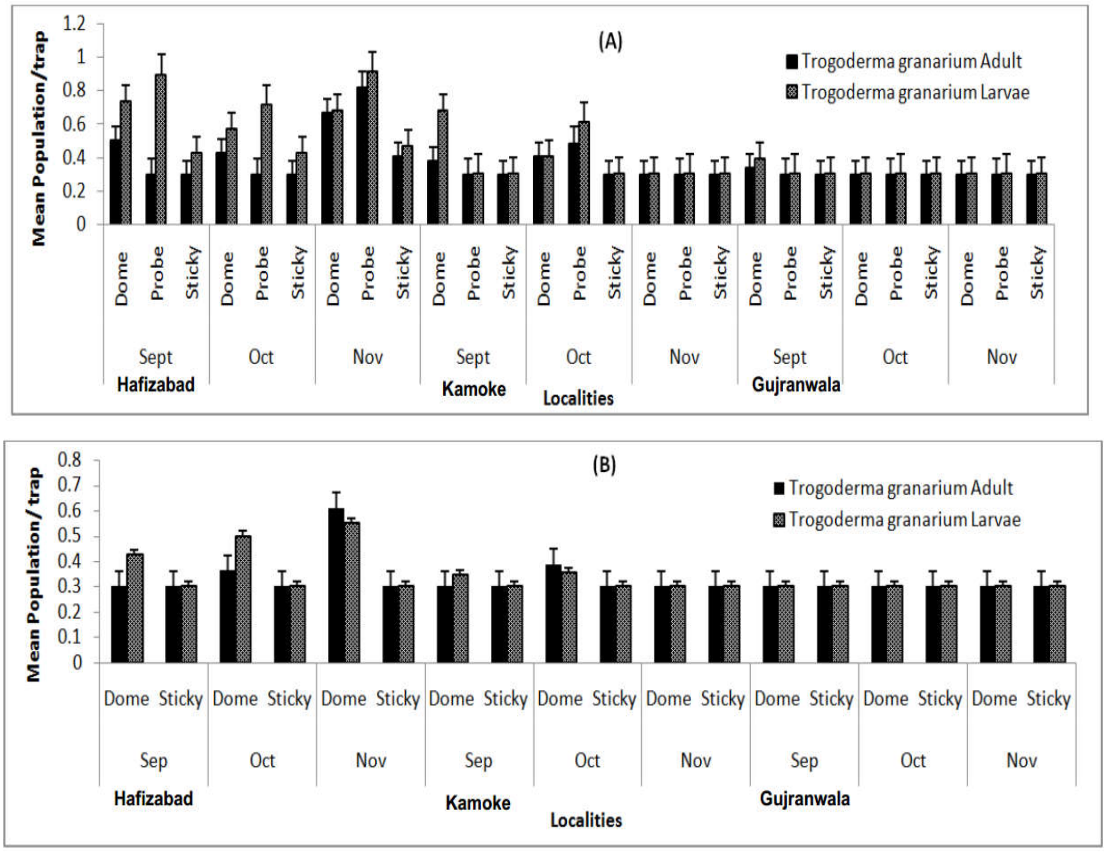
Statistical Analysis

Logarithm conversion factor of log (x+2) was applied to the number of insect catches in each traps (dome, probe, sticky) observed at three localities (Hafizabad, Kamoke and Gujranwala) over a period of three months (September, October and November). Data of insect counting in all traps were subjected to analysis of variance (ANOVA) and all pair wise comparisons were estimated using Least Significant Difference (LSD) test ($\alpha = 0.05$).

RESULTS

Mean Population of Khapra Beetle

Mean population of khapra beetle differed significantly among three localities. Furthermore, indoor vicinities of each rice processing unit showed significantly high population of khapra beetle as compared to outdoor vicinities in all three localities. In case of indoor vicinity ($F= 0.46$; $P= 0.87$) and out-door vicinity ($F= 1.09$; $P= 0.38$), khapra beetle adult population was found significantly high in Hafizabad locality followed by Kamoke.



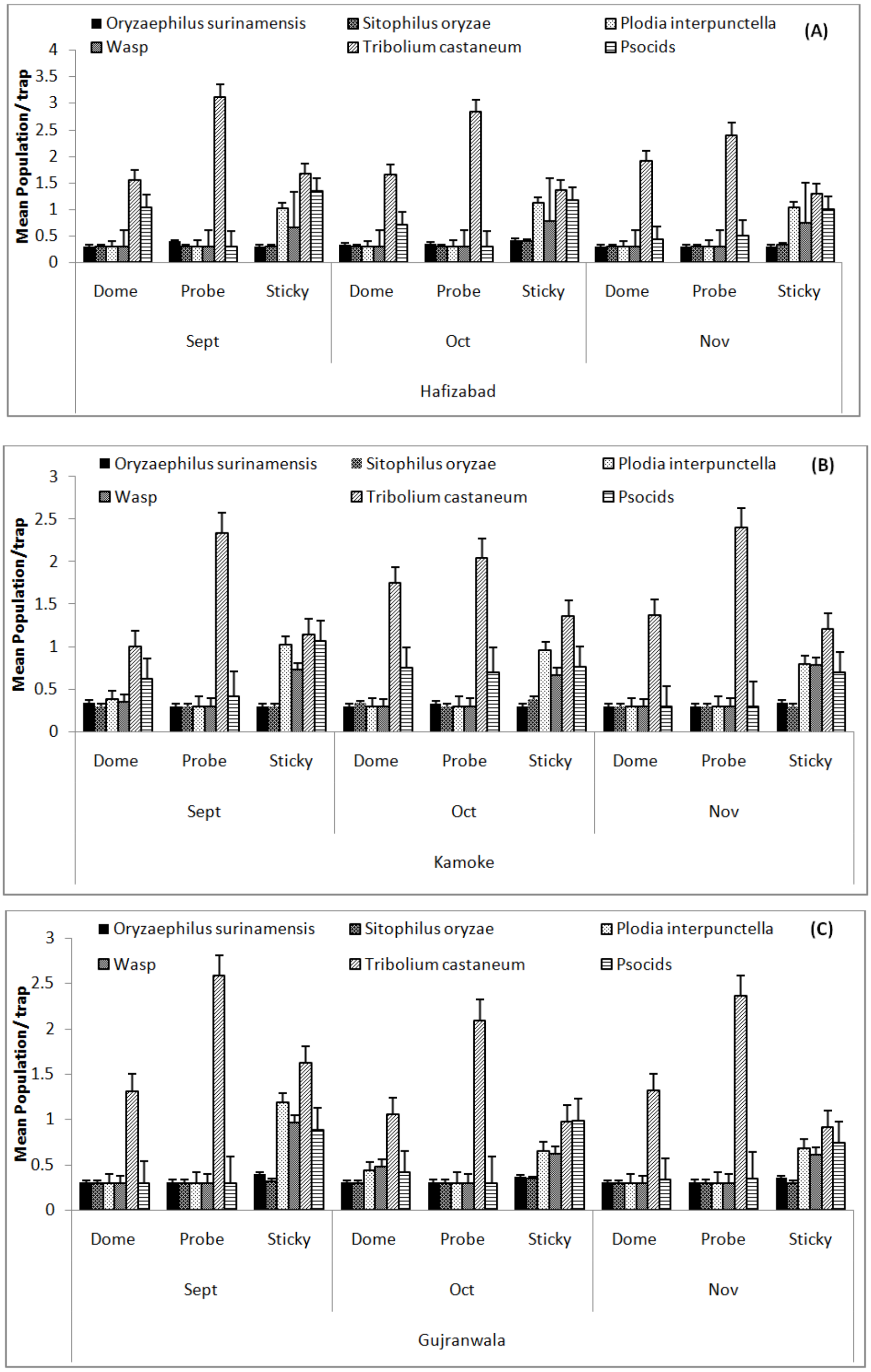
Logarithm conversion log(x+2) applied.

Figure 1. Mean population of Trogoderma granarium adult and larvae per trap; A- Indoor, B- Outdoor

Table 1. Indoor percent count/contribution of each insect with respect to total count of insects captured at Hafizabad (%)

Traps	Insect pest	Rice processing unit 1			Rice processing unit 2			Rice processing unit 3		
		Sep	Oct	Nov	Sep	Oct	Nov	Sep	Oct	Nov
Dome	*Trogoderma granarium* larvae	3.29	3.61	8.58	8.13	0	0	1.46	0	1.94
	Trogoderma granarium Adult	0.5	1.17	11.2	11.38	0	0	0	0	0
	Oryzaephilus surinamensis	0	0	0	0	0.75	0	0	0	0
	Sitophilus oryzae	0	0	0	0	0	0	0	0	0
	Plodiainterpunctella	0	0	0	0	0	0	0	0	0
	Hymenopterous Wasp	0	0	0	0	0	0	0	0	0
	Tribolium castaneum	89.05	89.66	75.8	80.49	99.25	100	42.23	48	98.06
	Psocids	7.16	5.56	4.42	0	0	0	56.31	52	0
	Total	100	100	100	100	100	100	100	100	100
Probe	*Trogoderma granarium* larvae	5.53	3.84	24.94	0.13	0	0	0	0	0
	Trogoderma granarium Adult	0	0	13.41	0	0	0	0	0	0
	Oryzaephilus surinamensis	0	0	0	0	0	0	0	0	0
	Sitophilus oryzae	0	0	0	0	0	0	0	0	0
	Plodiainterpunctella	0	0	0	0	0	0	0	0	0
	Hymenopterous Wasp	0	0	0	0	0	0	0	0	0
	Tribolium castaneum	94.47	96.16	58.9	99.87	100	100	100	100	100
	Psocids	0	0	2.75	0	0	0	0	0	0
	Total	100	100	100	100	100	100	100	100	100
Sticky	*Trogoderma granarium* larvae	2.89	4.45	13.84	0	0	0	0	0	0
	Trogoderma granarium Adult	0	0	4.02	0	0	0	0	0	0
	Oryzaephilus surinamensis	0.58	0.36	0	0	3.85	0	0	2.75	0
	Sitophilus oryzae	0	0	0.45	0	0.77	0	0	5.5	0
	Plodiainterpunctella	4.05	9.43	8.93	4.67	27.69	31.7	17.88	22.02	23.3
	Hymenopterous Wasp	1.51	2.85	4.91	1.91	10	13.85	3.63	10.1	5.48
	Tribolium castaneum	37.96	28.64	33.92	27.39	36.92	37.62	22.07	48.62	58.89
	Psocids	53.01	54.27	33.93	66.03	20.77	16.83	56.42	11.01	12.33
	Total	100	100	100	100	100	100	100	100	100

While Gujrawala locality was found depicting significantly low population of khapra beetle adult and larvae both in indoor and outdoor vicinity (Figure I). In case of indoor vicinities, in Hafizabad, dome traps were found significantly effective in capturing khapra beetle adult and maximum population was found during month of November (0.67±0.07) followed by September (0.50±0.07) and October (0.43±0.07). While probe traps showed significantly high population of khapra beetle larvae during month of November (0.91±0.12) followed by September (0.89±0.12) and October (0.71±0.12). In Kamoke, population of khapra beetle adult was significantly high in probe (0.48±0.09) and dome traps (0.41±0.07) during month of October.



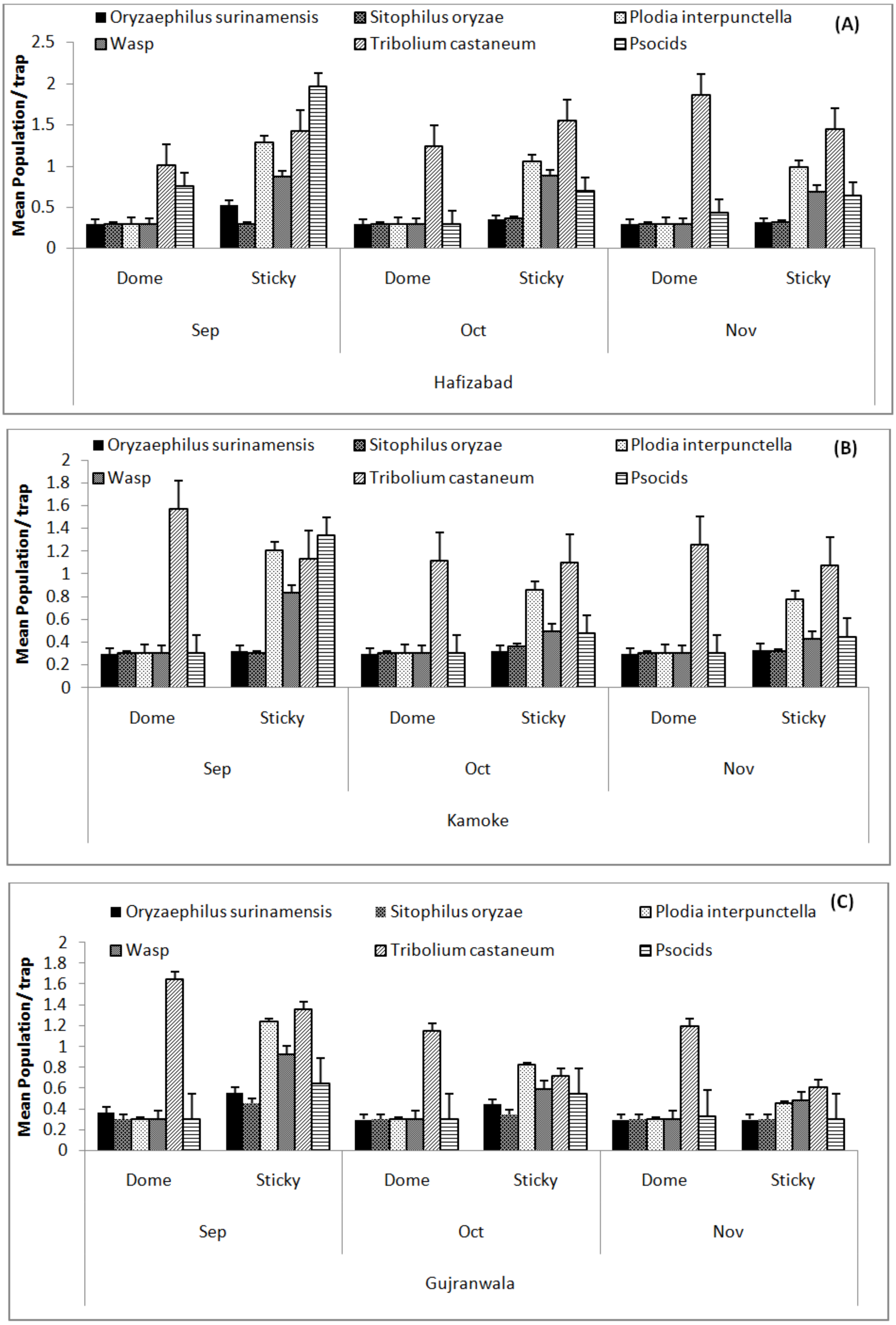
Logarithm conversion log(x+2) applied.

Figure 2(A-C). Indoor mean population of other stored grains pest per traps

While khapra beetle larval population was found significantly high in dome trap (0.67±0.09) during September and in probe traps (0.60±0.12) during October. Gujranwala locality was found to be depicting significantly negligible population of both khapra beetle adult and larval stage. The same population trend was observed in case of outdoor vicinity with respect to indoor vicinity of rice processing unit. Dome traps proved significantly effective in capturing both khapra beetle adult and larval stages in all three localities. In Hafizabad population of khapra beetle was significantly high (0.61±0.06 for adult and 0.55±0.02 for larva) during month of November. While a significantly low population of (0.38±0.06 for adult and 0.35±0.02) was observed during month of October at Kamoke. However, Gujranwala locality depicted negligible population of khapra beetle adult and larvae in all reporting months.

Mean Population of other stored grains insects

Mean population of other stored grains insect pests including *Oryzaephilus surinamensis, Plodiainterpunctella*, Psocids, *Sitophilus oryzae*, *Tribolium castaneum* and Hymenopterous wasp differed significantly among indoor and outdoor vicinities of rice processing units in all three localities (Hafizabad, Gujranwala and Kamoke). Indoor vicinities showed significantly high population of other stored grains insect pests as compared to outdoor vicinities in all three localities. Furthermore sticky traps were found significantly effective in capturing population of all concerned stored grains insect pests at all localities. Within all localities, *Tribolium castaneum* (F= 1.09; P= 0.39) was found significantly high as compared to other stored grains insects among all traps fixed at indoor vicinities. While in case of *Oryzaephilus surinamensis, Plodiainterpunctella*, Psocids, *Sitophilus oryzae* and Hymenopterous wasp, only sticky traps were found significantly effective in capturing their population as compared to dome and probe traps. Among these, *Plodiainterpeunctella* (F= 1.48; P= 0.19) and Psocids (F= 0.38; P= 0.92) were significantly high in population in all localities and *Sitophilus oryzae* was found significantly low (F= 1.25; P= 0.30) among all localities (Figure II). In outdoor vicinities of the rice processing units, the population trend of insect catches was similar to indoor vicinity. The significant difference was found only in case of *Tribolium castaneum*, where its population (F= 0.66; P= 0.62) was significantly reduced in dome and sticky traps as compared to indoor vicinity (Figure III).



Logarithm conversion log(x+2) applied.

Figure 3(A-C). Outdoor mean population of other stored grains pest per traps

Contribution/percent of each captured insect with respect to total count: In case of indoor vicinities, in all localities, *Tribolium castaneum, Trogoderma granarium*, Psocids and Wasps (in case of Gujranwala) contributed 100 percent of the collected population among Dome and Probe traps. While in sticky traps all eight captured insects including *T. granarium* (Larvae and adult), *O. surinamensis, S. oryzae, P. interpunctella,* Hymenopterous Wasp*, T. castaneum* and Psocidsmade their contribution as a population count. Furthermore, the *Trogoderma granarium* count was found significantly low in all traps among three localities (Table 1-3). In case of outdoor vicinities, only Dome and Sticky traps were used as monitoring tools. The percent count of all outdoor rice processing units showed similar trends with respect to indoor vicinities. However, *Trogoderma granarium* count was significantly low and was zero in seven rice processing units among nine experimental rice processing units (Tables 4-6).

Table 2. Indoor percent count/contribution of each insect with respect to total count of insects captured at Gujranwala (%)

Traps	Insect pest	Rice processing unit 1			Rice processing unit 2			Rice processing unit 3		
		Sep	Oct	Nov	Sep	Oct	Nov	Sep	Oct	Nov
Dome	*Trogoderma granarium* larvae	63.25	3.07	0	0	0	0	0	0	0
	Trogoderma granarium Adult	5.42	3.07	0	0	0	0	0	0	0
	Oryzaephilus surinamensis	0	0	0	2.24	0	0	0	0	0
	Sitophilus oryzae	0	0	0	0	0.36	0	0	0.51	0
	Plodiainterpunctella	6.63	0	0	0	0	0	0	0	0
	Hymenopterous Wasp	2.41	0	0	0	0	0	0	0	0
	Tribolium castaneum	10.84	37.93	100	58.96	99.64	100	100	99.49	100
	Psocids	11.45	55.93	0	38.80	0	0	0	0	0
	Total	100	100	100	100	100	100	100	100	100
Probe	*Trogoderma granarium* larvae	0	16.48	0	0	0	0	0	0	0
	Trogoderma granarium Adult	0	6.04	0	0	0	0	0	0	0
	Oryzaephilus surinamensis	0	0	0	0	0	0	0	0	0
	Sitophilus oryzae	0	0	0	0	0	0	0	0	0
	Plodiainterpunctella	0	0	0	0	0	0	0	0	0
	Hymenopterous Wasp	0	0	0	0	0	0	0	0	0
	Tribolium castaneum	100	42.86	100	94.89	100	100	100	100	100
	Psocids	0	34.62	0	5.11	0	0	0	0	0
	Total	100	100	100	100	100	100	100	100	100
Sticky	*Trogoderma granarium* larvae	0	0	0	0	0	0	0	0	0
	Trogoderma granarium Adult	0	0	0	0	0	0	0	0	0
	Oryzaephilus surinamensis	0	0	2.38	0	1.2	0	0	0	0
	Sitophilus oryzae	0	1.68	0	0	2.42	0	0	0	0
	Plodiainterpunctella	24.26	12.29	10.32	83.33	10.84	3.75	3.58	30.11	30
	Hymenopterous Wasp	8.88	3.35	6.35	16.67	2.41	13.75	1.97	17.61	21.43
	Tribolium castaneum	44.97	28.49	19.84	0	83.13	78.75	19.88	46.6	48.57
	Psocids	21.89	54.19	61.11	0	0	3.75	74.57	5.68	0
	Total	100	100	100	100	100	100	100	100	100

Table 3. Indoor percent count/contribution of each insect with respect to total count of insects captured at Kamoke (%)

Traps	Insect pest	Rice processing unit 1			Rice processing unit 2			Rice processing unit 3		
		Sep	Oct	Nov	Sep	Oct	Nov	Sep	Oct	Nov
Dome	*Trogoderma granarium* larvae	0	0	0	12.5	0	0	0	0	0
	Trogoderma granarium Adult	0	0	0	5.36	0	0	0	0	0
	Oryzaephilus surinamensis	0	0	0	3.57	0	0	0	0	0
	Sitophilus oryzae	0	0	0	0	0	0	0	0	0
	Plodiainterpunctella	0	0	0	0	18.9	0	0	0	0
	Hymenopterous Wasp	0	0	0	0	45.73	0	0	0	0
	Tribolium castaneum	100	100	100	78.57	22.56	97.1	100	100	100
	Psocids	0	0	0	0	12.81	2.9	0	0	0
	Total	100	100	100	100	100	100	100	100	100
Probe	*Trogoderma granarium* larvae	0	0	0	0	0	0	0	0	0
	Trogoderma granarium Adult	0	0	0	0	0	0	0	0	0
	Oryzaephilus surinamensis	0	0	0	0	0	0	0	0	0
	Sitophilus oryzae	0	0	0	0	0	0	0	0	0
	Plodiainterpunctella	0	0	0	0	0	0	0	0	
	Hymenopterous Wasp	0	0	0	0	0	0	0	0	0
	Tribolium castaneum	100	100	100	100	100	99.73	100	100	100
	Psocids	0	0	0	0	0	0.27	0	0	0
	Total	100	100	100	100	100	100	100	100	100
Sticky	*Trogoderma granarium* larvae	0	0	0	0	0	0	0	0	0
	Trogoderma granarium Adult	0	0	0	0	0	0	0	0	0
	Oryzaephilus surinamensis	0	0.62	0	2.37	0	8.16	0	1.96	0
	Sitophilus oryzae	0	1.88	0	0.47	0	0	0	0	0
	Plodiainterpunctella	2.02	25.63	28.38	29.86	0	8.16	42.96	4.58	7.76
	Hymenopterous Wasp	0.81	8.12	18.91	36.97	0	2.04	14.79	33.99	20.69
	Tribolium castaneum	74.09	32.5	45.95	30.33	100	77.54	38.73	0	4.31
	Psocids	23.08	31.25	6.76	0	0	4.1	3.52	59.47	67.24
	Total	100	100	100	100	100	100	100	100	100

Table 4. Outdoor percent count/contribution of each insect with respect to total count of insects captured at Hafizabad (%)

Traps	Insect pest	Rice processing unit 1			Rice processing unit 2			Rice processing unit 3		
		Sep	Oct	Nov	Sep	Oct	Nov	Sep	Oct	Nov
Dome	*Trogoderma granarium* larvae	6.04	15.52	5.89	0	0	0	0	0	0
	Trogoderma granarium Adult	0	3.45	9.89	0	0	0	0	0	0
	Oryzaephilus surinamensis	0	0	0	0	0	0	0	0	0
	Sitophilus oryzae	0	0	0	0	0	0	0	0	0
	Plodiainterpunctella	0	0	0	0	0	0	0	0	0
	Hymenopterous Wasp	0	0	0	0	0	0	0	0	0
	Tribolium castaneum	93.96	81.03	78.14	0	100	100	75	0	100
	Psocids	0	0	6.08	100	0	0	25	0	0
	Total	100	100	100	100	100	100	100	0	100
Sticky	*Trogoderma granarium* larvae	0	0	0	0	0	0	0	0	0
	Trogoderma granarium Adult	0	0	0	0	0	0	0	0	0
	Oryzaephilus surinamensis	0.65	0	0	0	0	0	23.57	1.82	0.62
	Sitophilus oryzae	0	0.9	0	0	1.11	0.44	0	0	0
	Plodiainterpunctella	13.99	33.33	31.87	2.77	15.13	18.34	13.38	8.64	10.56
	Hymenopterous Wasp	4.92	17.12	15.93	1.19	8.49	7.7	0	5.45	2.48
	Tribolium castaneum	11.14	48.65	52.2	3.9	42.43	46.33	28.02	84.09	86.34
	Psocids	69.3	0	0	92.14	32.84	27.1	35.03	0	0
	Total	100	100	100	100	100	100	100	100	100

Table 5. Outdoor percent count/contribution of each insect with respect to total count of insects captured at Gujranwala (%)

Traps	Insect pest	Rice processing unit 1			Rice processing unit 2			Rice processing unit 3		
		Sep	Oct	Nov	Sep	Oct	Nov	Sep	Oct	Nov
Dome	*Trogoderma granarium* larvae	1.33	2.34	0	0	0	0	0	0	0
	Trogoderma granarium Adult	0	4.69	0	0	0	0	0	0	0
	Oryzaephilus surinamensis	0	0	0	0	0	0	0	0	0
	Sitophilus oryzae	0	0	0	0	0	0	0	0	0
	Plodiainterpunctella	0	0	0	0	0	0	0	0	0
	Hymenopterous Wasp	0	0	0	0	0	0	0	0	0
	Tribolium castaneum	98.67	92.97	100	100	100	100	100	100	100
	Psocids	0	0	0	0	0	0	0	0	0
	Total	100	100	100	100	100	100	100	100	100
Sticky	*Trogoderma granarium* larvae	0	0	0	0	0	0	0	0	0
	Trogoderma granarium Adult	0	0	0	0	0	0	0	0	0
	Oryzaephilus surinamensis	0	1.3	2.86	0.79	0	0	0	0	0
	Sitophilus oryzae	0	3.9	1.43	0	0	0	0	1.18	0
	Plodiainterpunctella	25.48	23.38	22.86	22.22	32.43	34.29	10.97	23.53	19.67
	Hymenopterous Wasp	8.17	6.49	7.14	7.94	8.11	8.57	5.2	4.71	0
	Tribolium castaneum	50.48	59.74	61.43	36.51	59.46	57.14	6.69	44.71	55.74
	Psocids	15.87	5.19	4.28	32.54	0	0	77.14	25.87	24.59
	Total	100	100	100	100	100	100	100	100	100

Table 6. Outdoor percent count/contribution of each insect with respect to total count of insects captured at Kamoke (%)

Traps	Insect pest	Rice processing unit 1			Rice processing unit 2			Rice processing unit 3		
		Sep	Oct	Nov	Sep	Oct	Nov	Sep	Oct	Nov
Dome	*Trogoderma granarium* larvae	0	0	0	0	0	0	0	0	0
	Trogoderma granarium Adult	0	0	0	0	0	0	0	0	0
	Oryzaephilus surinamensis	0	0	0	6.67	0	0	2.9	0	0
	Sitophilus oryzae	0	0	0	0	0	0	0	0	0
	Plodiainterpunctella	0	0	0	0	0	0	0	0	0
	Hymenopterous Wasp	0	0	0	0	0	0	0	0	0
	Tribolium castaneum	100	100	100	93.33	0	95.92	97.1	100	100
	Psocids	0	0		0	0	4.08	0	0	0
	Total	100	100	100	100	0	100	100	100	100
Sticky	*Trogoderma granarium* larvae	0	0	0	0	0	0	0	0	0
	Trogoderma granarium Adult	0	0	0	0	0	0	0	0	0
	Oryzaephilus surinamensis	1.4	24.51	0	9.4	0	0	0	1.22	0
	Sitophilus oryzae	0.77	0	0	4.7	11.11	0	0	0	0
	Plodiainterpunctella	7.44	22.55	70.59	40.27	7.41	0	53.33	40.24	19.23
	Hymenopterous Wasp	3.26	12.75	29.41	15.43	29.63	42.1	22.67	7.32	11.54
	Tribolium castaneum	64.96	0	0	30.2	51.85	57.9	24	36.59	69.23
	Psocids	22.17	40.19	0	0	0	0	0	14.63	0
	Total	100	100	100	100	100	100	100	100	100

Later, Ahmad and Afzal (1984) recorded 22.7% post harvest loss in wheat, out of which 9.5% were reported occurring during storage of wheat. In case of storage structures, multiple pest infestations are very common for stored commodities and their population may vary significantly due to seasonal variation (Arthur*et al.*, 2014; Stejskal *et al*., 2014:2015). In stored grains insect pests monitoring system, usually surface and probe traps are used extensively and many studies indicating their species specific effectiveness has been given by many researchers (Trematerra, 1998; Buchelos and Athanassiou, 1999; Toews *et al*., 2005; Stejskal *et al*., 2008). The effectiveness of a trap also depends on category of internal and external feeders of the grains. Trematerra and Throne (2012) elaborated this concept and stated that most common internal feeders are *Sitophilus oryzae* and other insects like *Trogoderma granarium*, *Tribolium castaneum*, *Oryzaephilus surinamensis* and *Plodiainterpunctella*are external feeders of the stored grain. Furthermore, they also explained that external feeders are very rare in cereals but their infestation increases when internal feeders cause primary damage to kernals. Trematerra *et al*. (2000) observed that stored kernals that were infested by *Sitophilus oryzae* as primary pest got severe infestation of secondary pests like *O. surinamensis* and *T. castaneum*. Pitfall traps have been the simplest monitoring traps for detecting stored grains insect pests in rice (Carvalho *et al*., 2004). These have been used extensively in combination with probe traps in rice for monitoring beetle (Epenhuijsen *et al*., 2003). In our study, we also have observe that probe traps were more efficient as compared to dome and sticky traps for monitoring internal and external feeders of rice under storage conditions. Population of khapra beetle showed significant variation between different geographical locations. Hafizabad locality was recorded with significantly high population of khapra beetle larva and adult as compared to Kamoke and Gujranwala localities. Furthermore it was also found that prevalence of khapra beetle population is significantly abundant within indoor vicinities of rice processing warehouses while their population is negligible in outdoor vicinities. This revealed that movement of khapra beetle larva and adult was only confined within the storage structure in each locality and dispersal or contamination of storage warehouses from outside was not observed.

The storage durations of all three localities were up to two month, five months and nine months for Kamoke, Hafizabad and Gujranwala respectively. The relative humidity was maintained between 40-48%, 49-54% and 49-60% for Kamoke, Hafizabad and Gujranwala respectively. Furthermore, aluminum phosphide tablets were used in storage warehouses in Kamoke and Hafizabad and at Gujranwala, Cypermethrin, Static Spinosad and chlorpyriphos were applied in addition to aluminum phosphide by the owner of rice processing unit two months before start of the study. This suggests that significantly low population of khapra beetle larvae and adult were correlated with application of toxic insecticides within the storage structure as in case of Gujranwala where no population of khapra beetle was recorded in all three traps fixed indoor and outdoor of the rice processing units. In contrast to khapra beetle, the population of other stored grains insects was significantly high and consistent in all three localities (Hafizabad, Kamoke and Gujranwala). It is evident from results, that Hafizabad locality showed significantly high population of other insects as compared to Kamoke and Gujranwala. It also suggests that application of aluminum phosphide tablets and other insecticides used in storage structures did not give appropriate management against other stored grains insect pests. Furthermore, among other insects, the maximum population recorded of *Tribolium castaneum* also suggests the vulnerability of rice to this devastating pest following by Psocids. High population stored grains insects in localities where aluminium phosphine was used as fumigants may be due to the fact that resistance to aluminum phosphine has been reported already in case of these insects from different parts of the world including Pakistan (Mills, 1983; Benhalima, 1988; Ansell *et al*., 1990; Alam *et al*., 1999; Liang *et al*., 1999; Ahmedani *et al*., 2006; Valmas and Ebert, 2006). In many cases, resistance development was correlated with selection pressure exerted due to over usage of ineffective fumigation due to poor storage conditions and leakage of phosphine gas (Halliday *et al*., 1983).

Conclusion

Overall, keeping in view the aim of the study and insect count observed in case of Khapra beetle in all localities, the population of Khpara beetle was found very negligible and it suggests that this pests was well maintained within rice processing units and stored rice is kept on given standards before exporting to other countries. This uncovers the fact that interception may be provided in rice shipments during their transportation in combination with other grains and cereals and careful attention is needed while transporting the rice consignments to partner countries. It may be concluded that khapra beetle is not a major problem in rice processing units of Pakistan and is maintained using compatible management approaches. But based on the detection of high population of other insects in rice processing units, it is suggested to develop a sound management program to regulate population of these notorious internal and external grain feeders from rice supply chains of Pakistan.

Acknowledgement

Authors acknowledge USAID for providing financial assistance to conduct this study. We also appreciate the cooperation and contribution of REAP (Rice Exporters Associations of Pakistan) for making collaboration with rice processing units to monitor these insect pests.

REFERENCES

Ahmad, S.I and Afzal, M. 1984. Harvest and post-harvest losses in wheat. *Prog. Farm.,* 4, 31-35.

Ahmedani, M.S., Haque, M.I., Afzal, S.N., Naeem, M., Hussain, T. and Naz, S. 2011. Quantitative losses and physical damage caused to wheat kernel (Triticumaestivum L.) by Khapra beetle infestation. *Pak. J. Bot*., 43, 659-668.

Ahmedani, M.S., Khaliq, A., Aslam, M., Naz, S. and Ahmedani, M.Y. 2006. Fumigation Technique used in House Type Godowns for the Management of Resistant *Trogoderma granarium* larvae. *Pak. J. Arid Agric*., 9, 5-11.

Alam, M.S., Shaukat, S.S., Ahmed, M., Iqbal, S. and Ahmad, A. 1999. A survey of resistance to Phosphine in some coleopterous pests of stored wheat and rice grain in Pakistan. *Pak. J. Biol. Sci*., 2, 623-626.

Anonymous, 2014. Available at: http://www.thecropsite.com/news/16575/khapra-beetle-infestation-stops-rice-shipment-from-pakistan/.

Ansell, M.R., Dyte, C.E. and Smith, R.H. 1990. The inheritance of phosphine resistance in *Rhyzoperthadominica* and *Tribolium castaneum*. pp. 961-970. In: F. Fleurat-Lessard and P. Ducom, Editors, Proceedings of the Fifth International Working Conference on Stored product Protection. Bordeaux, France, 9-14 September 1990, Institut National de la Recherche Agronimique, Paris, France.

Arthur, F.H., Campbell, J.F., and Toews, M.D. 2014. Distribution, abundance, and seasonal patterns of stored product beetles in a commercial food storage facility. *J. Stored Products Res.,* 56, 21-32.

Azeem, M.I., Ahmad, M. and Haq, M. 1976. Relative susceptibility of some varities of wheat to Khpara beetle and brown grain beetle during storage. *Pak. J. Agric. Sci.,* 13, 36-66.

Baker, J.E., Arthur, F.H. and Brucker, P.L. 1991. Sesceptibility of 12 genotypes of triticale to the rice weevil (Coleoptera: Curculionidae) and the lasser grain borer (Coleoptera: Bostrichidae). *J. Entomol. Sci.,* 26, 334-339.

Benhalima, H. 1988. The detection and measurement of resistance to phosphine in three species of insect pests of stored cereals: *S. oryzae*, *R. dominica* and *T. castaneum*. M.Sc. dissertation, University of Edinburgh, Scotland, U.K.

Buchelos, C. and Athanassiou, C.G. 1999. Unbaited probe traps and grain trier: a comparison of the two methods for sampling Coleoptera on stored barley. *J. Stored Products Res.,* 35, 397-404.

Burkholder, W.E. 1990. Practical use of pheromones and other attractants for stored product insects. pp: 497-516. In R.L. Ridgway, R.M. Silverstein, and M.N. Inscoe (eds.), Behavior-modifying chemicals for insect management: applications of pheromones and other attractants. Marcel Dekker, New York.

Carvalho, M.O., Barbosa, A.F., Magro, A., Timlick, B., Adler, C., Marques, P., Teixeira, A., Jesus, O., and Mexia, A. 2004. Insects of stored rice in Portugal: fungus-feeders, commodity-feeders and beneficials. pp: 11–15. In: Proceedings 5th Meeting Cost Action 842, WG4 "Biocontrol of Arthropod Pests in Stored Products". Barcelona, Spain.

Chaudhary, M.A. 1980. Food grain losses at farm level in Pakistan. vol. 1. *Deptt. Agric. Marketing*, Univ. Agric., Faisalabad.

Ebeling, W. 2002. Pests of stored food products (in Urban Entomology, U.C. Riverside) pp: 1-43.

Epenhuijsen, van C.W., Bendall, M.J. and Sartie, A. 2003. A comparison of methods for trapping rice weevils in stored wheat. *New Zealand Plant Protec*., 56, 233-238.

Green, L. (2011) Khapra beetle larvae detected in rice. Available at: http//:Khapra%20Beetle%20Larvae%20 Detected%20in%20Rice%20_%20Colusa%20County%20News%20%E2%80%93%20Williams%20Pioneer%20Review.htm.

Hall, D.W. 1970. Handling and storage of food grains in tropical and subtropical areas, FAQ, Rome.

Halliday, D., Harris, A.H., and Taylor, R.W.D. 1983. Recent developments in the use of phosphine as a fumigant for grain and other durable agricultural produce. *Chem. Ind.,* 12, 468-471.

Hameed, M., Khattak, S.U. and Khatoon, R. 1989. Evaluation of wheat varities for resistance to Khapra beetle, Trogoderma granarium Everts. *J. Sci. Technol*., 13, 69-71.

Howe, R.W. 1965. Losses caused by insects and mites in stored food and feeding stuff. *Nutr. Abstr*., 35, 285-293.

Hubert, J., Stejaskl, V., Munzbergoba, Z., Kubatoba, A., Vanova, M. and Zdarkova, E. 2004. Mites and fungi in heavily infested stores in the Czech Republic. *J. Econ. Entomol.,* 97, 2144-2153.

Ismail, A.Y., Abid, S.H. and Mawlood, N.A. 1988. Effect of high temperature on the mortality of the red flour beetle *Triboliumconfusum*and khapra beetle *Trogoderma granarium*. *Zanco.,* 1, 35-42.

Ismail, I.I., Mostafa, T.S. and El-Keridees, B.B. 1988/89. Effect of food and light on reproductive capacity and rate of infestation of *Trogoderma granarium* Everts. *Bull. Soc. Entomol.,* 68, 159-168.

Jilani, G. 1981. Post-harvest protection of food grain with natural insect repellents. Prog. *Farm.,* 1, 66-29.

Karnavar, G.K. 1973. Prolonged starvation on survival and fecundity in *Trogoderma granarium. Current Sci.,* 42, 609-610.

Liang, Y., Yan, X., Qin, Z. and Wu, X. 1999. An alternative to the FAO method for testing phosphine resistance of higher-level resistance insects. pp: 607-611. In: Z. Jin, Q. Liang, Y. Liang, X. Tan and L. Guan, Editors, Stored Products Protection. Proceedings of the Seventh International Working Conference on Stored product Protection. 14-19 October 1998, Beijing, China, Sichuan Publishing House of Science and Technology, Chengdu, People's Republic of China.

Lindregen, D.L., Vincent, L.E. and Krohne, H.E. 1955. The khapra beetle, *Trogoderma granarium* Everts. Hilgradia., 24, 1-36.

Mills, K.A. 1983. Resistance to the fumigant hydrogen phosphide in some stored product insect species associated with repeated inadequate treatments. Mitteilungen der Deutschen Gesellschaft fur Allgemeine und Angewandte Entomologie., 4, 98-101.

Mullen, M.A. and Dowdy, A.K. 2001. A pheromone baited trap for monitoring the Indian meal moth, Plodiainterpunctella (Hubner) (Lepidoptera: Pyralidae). *J. Stored Prod. Res.,* 37, 231-235.

Nakakita, H. 1998. Stored rice and stored product insects. pp: 49-65. In: Rice inspection technology (Nakakita, H. ed), Tokoyo, A.C.E Corporation.

Phillips, T.W., Cogan, P.M. and Fadamiro, H.Y. 2000. Pheromones. pp: 273-302. In B. Subramanyam and D.W. Hagstrum (eds.), alternatives to pesticides in stored product IPM. Kluwer Academic, Boston, MA.

Ramzan, M. and Chahal, B.S. 1986. Effect of inter specific competition on the population build-up of some storage insects. *Ind. J. Ecol.,* 13, 313-317.

Reuters, 2013. Pakistan rice shipment rejected by US customs over invasive pest. Available at: file://Pakistan%20rice%20shipment%20rejected%20by%20US%20customs%20over%20invasive%20pest%20-%20Pakistan%20-%20DAWN.COM.htm.

Shafique, M. and Ahmad, M. 2003. Susceptibility of milled rice genotypes to Angoumois grain moth, Sitotrogacerealella (Oliv.) (Lepidoptera: Gelechiidae) SAARC *J. Agric.,* 1, 193-197.

Smith Jr, L.W., Pratt, J., Nii, I., and Umina, A.P. (1971) Baking and taste properties of bread made from hard wheat flour infested with species Tribolium, Tenebrio, Trogoderma and Oryzaphilus. *J. Stored. Prod. Res.,* 6, 307-316.

Sohi, G.S. 1986. Influence of food on the phototacic response of the larvae of *Trogoderma granarium* Everts (Dermestidae: Coleoptera). *Ind. J. Ecol.,* 13, 179-182.

Stejskal, V., Aulicky, R. and Kucerova, Z. 2014. Pest control strategies and damage potential of seed-infesting pests in the Czech stores – a review. Plant Prot. Sci., 50, 165–173.

Stejskal, V., Hubert, J., Aulicky, R. and Kucerova, Z. 2015. Overview of present and past and pest-associated risks in stored food and feed products: *European perspective. J. Stored Prod. Res.*, 64, 122-132.

Stejskal, V., Kucerova, Z., Aulicky, R. and Lukas, J. 2008. Method of sampling and laboratory extraction affects interpretation of grain infestation by storage pests. *J. Plant Dis. Prot.*, 115, 129-133.

Toews, M.D., Phillips, T.W., and Payton, M.E. (2005) Estimating populations of grain beetles using probe traps in wheat-filled concrete silos. *Environm. Entomol.,* 34, 712-718.

Trematerra, P. 1998. Capture of stored-grain coleopteran with WB Probe II Trap: Influence of grain type. Anzeigerfür Schadlingskunde, Pflanzenschutz, Umweltschutz., 71, 135-137.

Trematerra, P. 2013. Aspects related to decision support tools and Integrated Pest Management in food chains. Food Contr., 34, 733-742.

Trematerra, P. and Throne, J. 2012. Insect and mite pests of durum wheat. pp: 73-83. In: Sissons M., Abecassis J., Marchylo B., Carcea M. (eds): Durum Wheat, Chemistry and Technology. 2nd Ed. St. Paul, AACC International Inc.

Trematerra, P., Sciarretta, A. and Tamasi, E. 2000. Behavioural responses to volatiles from durum wheat kernels and host selection in *Oryzaephilus surinamensis* (Linnaeus), *Tribolium castaneum* (Herbst) and *Triboliumconfusum*J. du Val. *Entomol. Experiment. Appl.,* 94, 195-200.

Valmas, N. and Ebert, P.R. 2006. Comparative Toxicity of Fumigants and a Phosphine Synergist Using a Novel Containment Chamber for the Safe Generation of Concentrated Phosphine Gas. *PLoS ONE*., 1,1-30.

Vick, K.W., Mankin, R.W., Cogburn, R.R., Mullen, M., Throne, J.E., Wright, V.F. and Cline, L.D. 1990. Review of pheromone-baited sticky traps for detection of stored product insects. *J. kans. Entomol. Soc.,* 63, 526-532.

****