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Major insects of stored food grains

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Abstract
Insects are the major threat for causing the post-harvest losses in stored food grains. It causes the qualitative as well as quantitative losses in cereals, food legumes and oilseeds during the storage. To reduce the losses caused by insects, it is necessary to know the type of insects occurred in specific food grains. Damage caused by insect infestation in stored food grains affects the processing quality as well as reduced the nutritional quality. This article represents an overview of major insects of stored food grains.

Keywords: Insects, food legumes, oilseeds, cereals, storage

1. Introduction
About 10% of post–harvest losses are incurred in total food grains due to insects, rodents, micro-organisms, improper storage etc. In India, about 14 million tonnes (MT) of food grains of worth Rs. 7000 crores storage losses have been lost annually. Among these losses, insects alone are responsible for losses of about Rs. 1300 crores (Anonymous, 2015) [4]. Post-harvest losses due to storage and insect accounts for 2-4.2% (Kuamr and Kalta, 2017). Insects not only cause the losses in economic terms by consumption alone but also due to spreading contamination also. About 600 species of insects are occurred in stored grains and among these, about 100 species caused economic losses in stored grains (Neethirajan *et al*., 2007).

Several types of insect occurs which causes the infestation in stored food grains- primary, secondary and tertiary insect. Some insects are behave as free-living insects, visualized to the eye during the first examination and hidden insects are those insects which exist in individual grains due to their immature stage or due to their development in the grains. Insect's response to various natural and simulated features, classified into behavioral and metabolic responses. Movement of insects in stored grains in storage structures lies on environmental conditions. In the summer season, insect infestation occurs on the grain surface and disseminated in clumps throughout the mass, while in the winter season, insects flock in the lower and center portions of the storage structure. Attraction towards supportive conditions and evasion from fumigants, or treated surfaces comes into behavioral aspects whereas metabolic response includes the responses, which are used to promote or demote the development of insects (Bell, 2014) [11].

Primary insects are those which have the ability to bite or pierce intact and stable grains e.g. grain weevils (*Curculionidae*) major insect of stored cereal grains. Whole sound grains stable when its temperature and moisture content are below the levels required for germination. Primary insects attack the grain first. They have the ability to break down the hard seed coat of the whole grain and they laid the eggs inside the kernel, and the growing larvae cause the infestation inside of the kernel. Primary insects often develop and reproduce very quickly in the optimal conditions, which allows for large populations. They are usually more destructive than secondary pests, especially in short-term storage of food grains (Banga *et al*., 2018) [7].

Secondary insects follow the primary insects. They feed the grains that are broken by the primary insects, processed into products viz. flour, dal etc. or damaged by poor threshing, drying and handling e.g. red flour beetle (*Tribolium castaneum*) common secondary insect of wheat. Secondary insects eat the grain from the outside first. The presence of secondary insect often indicates that the grain is not in superlative condition and that measures should be implemented to protect the grain from a further decline in quality. Tertiary insects feed on broken grains, grain dust, and powder left by the primary and secondary insects.

Confused flour beetle is a tertiary insect of whole grains. Also, it is a secondary insect of milled grains such as flour.

2. Problems Due to Infestation

Infestation caused by insects imposed several losses viz. weight loss, viable value loss, and Commercial value loss, nutritional loss health hazards, storability loss etc. (Neethitrajan *et al*., 2007; Banga *et al*., 2018) [7]

3. Major Insects of Stored Food Grains

High post-harvest losses during storage are mainly occurred by two major groups of insects: Coleoptera (beetles) and Lepidoptera (moths and butterflies). Lepidoptera damage the grain during the larvae stage while in the case of Coleoptera, both larvae and adults damage the grain (Sallam, 2008) [44]. Coleoptera causes the more destruction in stored food grains as compared to lepidoptera (Upadhyay and Ahmad, 2011) [54]. Prevention of insect infestation in stored food grains requires low moisture content and low temperature. The safe moisture content for long term storage of cereals should be below 12%, pulses are 10-12% and 7-9% for oil seeds (Chakravarty, 2014). The safe grain storage temperature for grains should be kept below 5 °C for mites, 15 °C for insects and 10°C for molds (Chakravarty, 2014) [14]. Evolution of insects molds and mites seized below 10% and 13% moisture content in stored food grains (Banga *et al*., 2018) [7]. Major insects of stored foodgrains with their classification, life span etc. is entitled in table 1. Bulk storage of food grains also affects the infestation rate, 50 MT or larger stored food grain in silos/bins cools slowly and hence may cause more spoilage as compared to the smaller structures with a capacity of 27 tonnes or lesser (Kumar & Rai, 2014) [25].

Table 1: Summary of Major Stored Food Grain Insects

Common Name	Family (order)	Scientific name	Survival commodity	Life span	References
Cereals					
Lesser grain borer	Bostrichidae (Coleoptera)	*Rhyzopertha dominica* (Fabricius)	Infest all cereal grains, but mostly occurs in wheat, corn, rice and millet	25 days at 34 °C.	Edde, 2012 [16]
Granary weevil	Curculionidae (Coleoptera)	*Sitophilus granarius* (L.)	wheat, corn, rye, oats, barley, sorghum	25-38 days at 30 °C and 70% RH	Pražić-Golić *et al.*, 2011 [39]
Rice weevil	Curculionidae (Coleoptera)	*Sitophilus oryzae* (L.)	Rice, wheat, barley, occasionally peas	25 days at 29.1 °C and 70% RH.	Batta, 2004 [9]
Maize weevil	Curculionidae	*Sitophilus zeamais Motschulsky*	Maize, Grain, pasta	26 days at 30 °C and 75 to 76% RH. About 10 generations in a year.	Rees, 2004 40]; Kranz *et al.*, 1997 [23]
Rusty grain beetle	Laemophloeidae (Coleoptera)	*Cryptolestes ferrugineus* (Stephens)	Wheat, barley, rye, triticale, oats, and occasionally milled products	Up to 9 months.	Neethirajan *et al.*, 2007
Flour mill beetle	Laemophloeidae (Coleoptera)	*Cryptolestes turcicus* (Grouvelle)	Flour, damaged grain Waste grain	Average life span is 1 year, 17-37 °C and relative humidity 90%.	Neethirajan *et al.*, 2007
Merchant grain beetle	Silvanidae (Coleoptera)	*Oryzaephilus mercator* (Fauvel)	Prefers processed cereals, and flours	14- 46 days at 20 ºC, and at optimum condition of 30–32·5 °C.	Pierce *et al.*, 1990
Saw-toothed grain beetle*	Silvanidae (Coleoptera)	*Oryzaephilus surinamensis* (L.)	Oats, wheat, barley, animal feed, flax, sunflower	3-4 weeks at above 30 ºC; longer life during cooler months.	Mowery *et al.*, 2002
Long headed flour beetle	Tenebrionidae (Coleoptera)	*Latheticus oryzae* Waterhouse	Sorghum, maize	Adults live for up to 112 days, requires 25 ºC requires for development to occur.	Atwa, 1986
Red flour beetle**	Tenebrionidae (Coleoptera)	*Tribolium castaneum* (Herbst)	Stored grains, oilseeds Starchy materials, beans, peas	30 days in summer but longer life in winter.	Neethirajan *et al.*, 2007
Confused flour beetle**	Tenebrionidae (Coleoptera)	*Tribolium confusum*	Grains, cereal products, flour, animal feed, sunflower, millet Starchy materials, beans, peas, spices	42 days at above 30 ºC	Baldwin and Fasulo, 2003 [6]
Large flour beetle	Tenebrionidae (Coleoptera)	*Tribolium destructor Uyttenboogaart*	Seeds, cereals, flour, stored grain, bran	Adults survive up to 1 year, Survive below 30 °C.	Schreurs and Janovy, 2008 [46]
Angoumois grain moth	Gelichiidae (Lepidoptera)	*Sitotroga cerealella* (Olivier)	Wheat, barley, corn, rice, sorghum, millet	35 days at 30 °C and 75-76% RH.	Saikia *et al.*, 2014 [43]
Indian meal moth	Pyralidae (Lepidoptera)	*Plodia interpunctella*	Most common moth pest of stored grains.	28-35 days at optimum condition of 30-35 °C and 25% relative humidity.	Mewis and Ulrichs, 2001 [29]
Yellow mealworm	Tenebrionidae (Coleoptera)	*Tenebrio molitor* L.	Prefers decaying grain or milled cereals	Larvae survive up to 21 days at 15 °C.	Sadd *et al.*, 2006 [42]; Upadhyay and Ahmad, 2011 [54]
Pulses					
Bean Weevil	Chrysomelidae (Coleoptera)	*Acanthoscelides obtectus*	Beans, lentil, chickpea, soybean	21-28 days at the temperature above 30	Regnault-Roger *et al.*, 1995 [41]

				°C; more proliferation in cooler months. 5-6 generations in a year.	
Pea Weevil	Chrysomelidae (Coleoptera)	*Bruchus pisorum* (Linnaeus)	Peas	21 days at 30 °C and 70% RH	Sarwar, 2015 [42]
Cowpea beetle	Chrysomelidae (Coleoptera)	*Callosobruchus maculatus*	Cowpea, beans, peas, green gram	10-14 days. More proliferation in cooler months.	Tiroesele, 2014 [53]; Devi *et al.*, 2014 [15]
Pulse beetle	Chrysomelidae (Coleoptera)	*Callosobruchus chinensis* (L.)	Green gram, lentil, chickpea, cowpea and pigeon pea	21 days at 30 °C and 70% RH.	Patel *et al.*, 2005 [36]; Pokharkar and Mehta, 2011 [38]
Cereals and Pulses					
Flat grain beetle	Laemophloeidae (Coleoptera)	*Cryptolestes pusillus* (Schönherr)	Cereals and pulses	4-5 weeks and adults may survive up to one year. Larvae developed at a higher rate at 90% than at 70% relative humidity.	Millar *et al.*, 1985 [30]
Oilseeds					
Khapra beetle	Dermestidae (Coleoptera)	*Trogoderma granarium* Everts	Grains and oilseeds	14-30 days in high humidity regions.	Ahmedani *et al.*, 2007 [2]

*Survive in both cereals and oilseeds
** Survive in cereals, oilseeds, and pulses

3.1 Infestation in Cereals
In developing countries viz. India, about 50-60% of food grains are stored in traditional storage structures and at farm level (Anonymous, 2014; Kumar and Kalita, 2017) [3, 24] and about 30-40% losses are occurred in the grains due to insect infestation (Boxall, 2002; Abass *et al.*, 2014) [1]. Losses incurred from insect infestation are boundless and commits quality loss, quantity loss, and grade (Harein and Meronuck, 1995). *Rhizopertha dominica* F. and *Trogoderma granarium* are the two most calamitous insects for stored cereal grains. In 1980, Boxall, (2002) reported the 50% losses in stored maize due to insect infestation. Pantenius (1988) found that about 80-90% losses during storage of maize occurred due to insect infestation. Jha *et al.* (2015) found that total storage losses including godowns, wholesale retailers, and processing unit acquired 0.86, 0.86, 0.75, 0.79, and 1.21% in wheat, paddy, maize, millet, and sorghum, respectively. Khaliq *et al.* (2014) determined the nutritional losses in rice genotypes at 28 °C, 32 °C and 35 °C against *Tribolum castaneum (Herbst).* They found that insects caused reasonable losses in nutritional characteristics. Effect of storage and *Sitophilus granarius* on the technological properties of wheat was studied and found that kernel and fat content decreased, and due to this bread properties deteriorated (Keskin and Ozkaya, 2015). Larger grain borers (*Prostephanus truncatus*) and maize weevil (*Sitophilus zeamais)* major stored pest of maize, caused 23% losses during 6 months storage and 56.7% losses after 6 months storage (Kumar and Kalita, 2017, Abass *et al.*, 2014 and Kimenju *et al.*, 2010) [24, 1]. Lesser grain borer is the most dangerous insect, caused about 30% weight loss in stored maize (Boxall, 2002) [13]. Patel *et al.* (1993) [35] found that *R. dominica* caused 25% losses in stored wheat. Storage losses can be reduced by using the appropriate storage structures such as infestation level of *C. maculatus* on the seeds during the four months storage was reduced in Super grain bags as compared to the PICS (Purdue Improved Crop Storage) bag (Baoua *et al.*, 2014) [10]. Somavat *et al.* (2014) reported the compared results of hermetic bin bags, metallic bins and gunny bags and found that there was no infestation in hermetic bags after nine months of wheat storage and seed viability was higher (88%) in hermetically stored grains (Somavat *et al.*, 2015 and Kumar *et al*., 2017) [50, 24].

3.2 Infestation in Food Legumes
During storage of food legumes in storage or on farm structures prior to processing, many physiological changes occurs which causes the reduction in quantitative as well as qualitative and therefore economic losses (Banga *et al.*, 2019) [8]. Mookherjee *et al.* (1970) [32] and Gangrade (1974) [18] found that infestation in pulses occurred due to bruchids, which causes the major losses in pulses during storage. Bruchids eat the whole kernel and left only the pericarp, which makes the seed inedible and unfeasible. In pulses, about 90% of infestation are arises due to *Callosobruchus chinesis, Callosobruchus maculatus* and *Callosobruchus analis* in India (Sivakumar, 2010) [48]. Among these species of genus *Callosotbruchus, C. maculatus* and *C. chinensis* are one of the most calamitous insect during storage of cowpea, chickpea, mung, garden pea, black gram, lentil, and pigeon pea (Iturralde-García *et al.*, 2016; Banga *et al.*, 2018) [7, 21]. These insect assails wild and cultivated legumes, specifically *Vigna radiata* (Messina and Mitchell, 1989) [28]. Losses incurring in stored pulses by *C. chinensis* infestation has been reported from Philippines, Japan, Indonesia, Sri Lanka, Burma, India and Bangladesh (Mahdi and Rahman, 2008) [27]. Gujar and Yadav, (1978) reported that about 55-69% seed weight loss and 45.6-66.3% loss in protein content of chickpea by the pulse beetle. In Nigeria, about 24% losses in stored pulses occurred due to *C. maculatus* (Tapondjou *et al.*, 2002). In tropical regions insect leads to 100% detrimental effects in stored pulses (Egwuatu, 1987) [17]. Birewar, (1984) [12] reported about 9.5% of post-harvest losses in pulses, in which about 7.5% losses occurred due to storage alone. In chickpea and lentil, about 30% and 15% storage losses found in India, respectively. About 10-15% losses along with 50-92% germination losses are caused by bruchids in stored cereals and pulses (Haile, 2006) [20]. Mutungi *et al.* (2014) [34] determined the efficacy of the PICS bags under natural infestation and artificial infestation in green gram and pigeonpeas and found the average change in infestation level of both the condition of PICS stored legumes. Singh *et al.* (2012) [27] evaluated the mortality of *C. chinensis,* treated by microwave radiation and found that seed viability and germination of chickpea, pigeon pea, and green gram decreased with microwave radiation exposed time and power

level. Mohapatra *et al*. (2014) [31] reported the effect of microwave heating on adult *C. maculatus* for different grain bed thickness and concluded that microwave heating had no significant effect on moisture loss, cooking time and protein content.

3.3 Infestation in oilseeds

A large variety of pests damage oilseeds and cause significant losses in the farms or during storages. Insects cause significant economic losses in oilseeds. Classification of oilseed insect pest depends on taxonomic grouping, distribution and feeding habitat. Insect infestation of sunflower kernels during storage affected the kernel and reduced the oil content due to increase in moisture content and temperature. Soybean can be safely stored at maximum safe drying temperatures are 43 °C for soybeans intended for seeding purposes and 49 °C for commercial use.

4. Conclusion

Insects infestation in stored grains causes a huge loss by contaminating it or by eating it. Therefore it is necessary to understand the behavior, type of insects and their life cycle to reduce the post-harvest losses. Knowledge of insects would also help in monitoring and assessment of their damage in stored food grains by adopting the suitable technology. It should be necessary to grain storage handlers to know about the insects morphology and apply the appropriate technology to reduce the losses caused by them. It is need of time to reduce the post-harvest losses of food grains to fulfill the requirement of increasing population.

5. References

1. Abass AB, Ndunguru G, Mamiro P, Alenkhe B, Mlingi N, Bekunda M. Post-harvest food losses in a maize-based farming system of semi-arid savannah area of Tanzania. Boxall, R. A. Damage and loss caused by the larger grain borer *Prostephanus truncatus*. Journal of Stored Products Research. 2014; 57:49-57.
2. Ahmedani MS, Abdulkhalig MT, Tarig M, Anwar M, Naz S. Khapra beetle (*Trogoderma granarium* Everts): A serious threat to food security and safety. Pak. J. Agri. Sci, 2007; 44(3):481-493.
3. Anonymous. Food and Agriculture Organization of United Nations. Global Initiative on Food Losses and Waste Reduction; FAO: Rome, Italy. 2014.
4. Anonymous. Indian Grain Storage Management and Research Institute, Hapur, Ministry of Consumer Affairs, Food and Public Distribution, Department of Food and Public Distribution, Government of India. 2015.
5. Atwa WAA. Biological studies on Latheticusoryzae Waterhouse (Coleoptera: Tenebrionidae). *Monoufeya* Journal of Agricultural Research (Egypt). 1986.
6. Baldwin R, Fasulo TR. Confused Flour Beetle, *Tribolium confusum* Jacquelin du Val (Insecta: Coleoptera: Tenebrionidae) and Red Flour Beetle, *Tribolium castaneum* (Herbst) (Insecta: Coleoptera: Tenebrionidae). USA: University of Florida IFAS Extension. 2003.
7. Banga KS, Kotwaliwale N, Mohapatra D, Giri SK. Techniques for insect detection in stored food grains: An overview. Food Control. 2018; 94:167-176.
8. Banga KS, Kotwaliwale N, Mohapatra D, Giri SK, Babu VB. Bioacoustic detection of *Callosobruchus chinensis* and *Callosobruchus maculatus* in bulk stored chickpea (*Cicer arietinum*) and green gram (*Vigna radiata*). Food Control, 2019; 104:278-287.
9. Batta YA. Control of rice weevil (*Sitophilus oryzae* L., Coleoptera: Curculionidae) with various formulations of *Metarhizium anisopliae*. Crop Protection. 2004; 23(2):103-108.
10. Baoua IB, Amadou L, Baributsa D, Murdock LL. Triple bag hermetic technology for post-harvest preservation of Bambara groundnut (*Vigna subterranea* (L.) Verdc.). Journal of Stored Products Research. 2014; 58:48-52.
11. Bell CH. A review of insect responses to variations encountered in the managed storage environment. Journal of Stored Products Research. 2014; 59:260-274.
12. Birewar, B.R. Post-Harvest Technology of Pulses, Pulse Production - Constraints and Opportunities. Oxford and IBH Publishing Co., New Delhi, India. 1984, 425-438.
13. Boxall RA. Damage and loss caused by the larger grain borer *Prostephanus truncatus*. Integrated Pest Management Reviews, 2002; 7(2):105-121.
14. Chakravarty A. Post-Harvest Technology of Cereals, Pulses and oilseeds, third edition, Oxford & IBH Publishing Co. Pvt. Ltd. 2014.
15. Devi MB, Devi NV. Biology and morphometric measurement of cowpea weevil, *Callosobruchus maculatus* Coleoptera: Chrysomelidae) in green gram. Journal of Entomology and Zoology Studies, 2014, 2(3):74-76.
16. Edde, Peter A. A review of the biology and control of *Rhyzopertha dominica* (F.) the lesser grain borer. Journal of Stored Products Research. 2012; 48:1-18.
17. Egwuatu RI. Current status of conventional insecticides in the management of stored product insect pests in the tropics. International Journal of Tropical Insect Science. 1987; 8(4-5-6):695-701.
18. Gangrade GA. Insects of soybean. Technical Bulletin Jawaharlal Neru Krishi Vishwa Vidyalaya, 1974; 24:88.
19. Gujar GT, Yadav TD. Feeding of *Callosobruchus maculatuts* (Fab.) and *Callosobruchus chinensis* (Linn.) in green gram. Indian journal of entomology. 1978.
20. Haile, A. On-farm storage studies on sorghum and chickpea in Eritrea. African Journal of Biotechnology. 2006, 5(17).
21. Iturralde-García RD, Borboa-Flores J, Cinco-Moroyoqui FJ, Riudavets J, Del Toro-Sánchez CL, Rueda-Puente, Effect of controlled atmospheres on the insect *Callosobruchus maculatus* Fab. in stored chickpea. Journal of Stored Products Research, 2016; 69, 78-85.
22. Kimenju SC, De Groote H. Economic analysis of alternative maize storage technologies in Kenya. In Joint 3rd African Association of Agricultural Economists (AAAE) and 48th Agricultural Economists Association of South Africa (AEASA) Conference, Cape Town, South Africa, 2010, 19-23.
23. Kranz JK, Schmutterer H, Koch W. Diseases, pests and weeds in tropical crops. New York: Wesly, 1997, 666.
24. Kumar D, Kalita P. Reducing Postharvest Losses during Storage of Grain Crops to Strengthen Food Security in Developing Countries. Foods, 2017; 6(1):8.
25. Kumar G, Rai DV. Management strategies for storage, disinfestation and insect detection of grains and seeds. Progressive Agriculture. 2014; 14(1):87-101.
26. Kumar S, Mohapatra D, Kotwaliwale N, Singh KK, Vacuum Hermetic Fumigation: A review. Journal of Stored Products Research, 2017; 71:47-56.

27. Mahdi SHA, Rahman MK. Insecticidal effect of some spices on *Callosobruchus maculatus* (Fabricius) in black gram seeds. University journal of zoology, Rajshahi University, 2008; 27:47-50.
28. Messina FJ, Mitchell, R. Intraspecific variation in the egg-spacing behavior of the seed beetle *Callosobruchus maculatus*. Journal of Insect Behavior, 1989; 2(6):727-742.
29. Mewis I, Ulrichs C. Action of amorphous diatomaceous earth against different stages of the stored product pests *Tribolium confusum*, *Tenebrio molitor*, *Sitophilus granarius* and *Plodia interpunctella*. Journal of Stored Products Research, 2001; 37(2):153-164.
30. Millar JG, Pierce HD, Pierce AM, Oehlschlager AC, Borden JH, Barak AV. Aggregation pheromones of the flat grain beetle, *Cryptolestes pusillus* (Coleoptera: Cucujidae). Journal of chemical ecology, 1985; 11(8):1053-1070.
31. Mohapatra D, Giri SK, Kar A. Effect of microwave aided disinfestation of *Callosobruchus maculatus* on green gram quality. International Journal of Agriculture and Food Science Technology, 2014; 5(2):55-62.
32. Mookherjee PB, Jotwani MG, Yadav TD, Sricar P. Studies on incidence and extent of damage due to insect pest in stored seeds II leguminous and vegetable seeds. Indian Journal of Entomolgy, 1970; 32:350-355.
33. Mowery SV, Mullen MA, Campbell JF, Broce AB. Mechanisms underlying saw-toothed grain beetle (*Oryzae philussurinamensis* [L.]) (Coleoptera: Silvanidae) infestation of consumer food packaging materials. Journal of Economic Entomology, 2002; 95(6):1333-1336.
34. Mutungi CM, Affognon H, Njoroge AW, Baributsa D, Murdock LL. Storage of mung bean (*Vigna radiata* [L.] Wilczek) and pigeonpea grains (*Cajanus cajan* [L.] Millsp) in hermetic triple-layer bags stops losses caused by *Callosobruchus maculatus* (F.) (Coleoptera: Bruchidae). Journal of Stored Products Research, 2014; 58:39-47.
35. Patel KP, Valand VM, Patel SN. Powder of neem-seed kernel for control of lesser grainborer (*Rhizopertha dominica*) in wheat (*Triticum aestivum*). Indian Journal of Agricultural Sciences (India). 1993.
36. Patel VK, Chaudhuri N, Senapati SK. Biology of pulse beetle (*Callosobruchus chinensis* Linn.) as influenced by feeding of different grain pulses. Agricultural Science Digest, 2005; 25(4):254-256.
37. Pierce AM, Pierce HD, Oehlschlager AC, Borden JH. Attraction of *Oryzaephilus surinamensis* (L.) and *Oryzaephilus mercator* (Fauvel) (Coleoptera: Cucujidae) to some common volatiles of food. Journal of chemical ecology, 1990; 16(2):465-475.
38. Pokharkar PK, Mehta DM. Biology of pulse beetle, *Callosobruchus chinensis* in stored chickpea. Progressive Agriculture, 2011; 11(1):34-36.
39. Pražić-Golić M, Andrić G, Kljajić P. Effects of 50 C temperature on *Sitophilus granarius* (L.), *Sitophilus oryzae* (L.) and Sitophilus zeamais (Motsch.). *Pesticidi fitomedicina*, 2011; 26(3):221-227.
40. Rees DP. Insects of stored products. Manson Publishing Ltd. London, 2004.
41. Regnault-Roger C, Hamraoui A. Fumigant toxic activity and reproductive inhibition induced by monoterpenes on *Acanthoscelides obtectus* (Say) (Coleoptera), a bruchid of kidney bean (*Phaseolus vulgaris* L.). Journal of Stored Products Research. 1995; 31(4):291-299.
42. Sadd B, Holman L, Armitage H, Lock F, Marland R, Siva- Jothy MT. Modulation of sexual signalling by immune challenged male mealworm beetles (*Tenebrio molitor*, L.): evidence for terminal investment and dishonesty. Journal of evolutionary biology, 2006, 19(2):321-325.
43. Saikia J, Goswami MM, Bhattacharyya B. Biology and detection technique of Angoumois grain moth, *Sitotroga cerealella* Olivier (Lepidoptera: Gelechiidae) on stored rice and maize grains. J. Entomol. Zool. Stud, 2014, 2:9-11.
44. Sallam MN. Insect damage: damage on post-harvest. AGSI/FAO: INPhO. 2008. Available via http://www. fao. org/inpho/content/compend/text/ch02-01. htm. Accessed, 22.
45. Sarwar M. Distinguishing and controlling insect pests of stored foods for improving quality and safety. American Journal of Marketing Research. 2015; 1(3):201-207.
46. Schreurs J, Janovy Jr, J. Gregarines on a diet: The effects of host starvation on Gregarina confuse (Apicomplexa: Eugregarinida) in Tribolium destructor Uyttenboogaart, (Coleoptera: Tenebrionidae) larvae. Journal of Parasitology. 1933, 2008, 94(3):567-570.
47. Singh R, Singh KK, Kotwaliwale N. Study on disinfestation of pulses using microwave technique. Journal of food science and technology. 2012; 49(4):505-509.
48. Sivakumar C, Chandrasekaran S, Vijayaraghavan C, Selvaraj S. Fumigant toxicity of essential oils against pulse beetle, *Callosobruchus maculates* (F.) (Coleoptera: Bruchidae), J Biopesticides, 2010; 3(1):317-319.
49. Somava P, Huang H, Kumar S, Garg MK, Danao MGC, Singh V *et al.* Comparison of Hermetic Storage of Wheat with Traditional Storage Methods in India. In 2014 Montreal, Quebec Canada July 13–July 16, 2014 (p. 1). American Society of Agricultural and Biological Engineers. 2014.
50. Somavat P, Huang H, Kumar S, Garg M, Danao M, Singh V *et al.* Hermetic wheat storage for small holder farmers in India. In Proceedings of the First International Congress on Postharvest Loss Prevention, Rome, Italy. 2015.
51. Srivastava C, Subramanian S. Storage insect pests and their damage symptoms: an overview. Indian Journal of Entomology. 2016; 78(special):53-58.
52. Tapondjou LA, Adler CLAC, Bouda H, Fontem DA. Efficacy of powder and essential oil from *Chenopodium ambrosioides* leaves as post-harvest grain protectants against six-stored product beetles. Journal of stored products Research. 2002; 38(4):395-402.
53. Tiroesele B, Thomas K, Seketeme S. Control of cowpea weevil, *Callosobruchus maculatus* (F.) (Coleoptera: Bruchidae), using natural plant products. Insects, 2014; 6(1):77-84.
54. Upadhyay RK, Ahmad S. Management strategies for control of stored grain insect pests in farmer stores and public ware houses. World J Agric Sci. 2011; 7:527-549.