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Research Article

Assessing storage insect pests and post-harvest loss of maize in major producing areas of Ethiopia

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Abstract

The survey was conducted for three years from 2018 to 2020 cropping seasons in four regions, Amahara, Oromia, SNNP and Benishangul Gumuz, to identify storage insect pests and to assess post-harvest loss of maize in major producing areas Ethiopia. All the collected data were analyzed by using the SPSS software and difference among means were also compared. A total of 280 farmers field were surveyed. 98% of the surveyed farmers used traditional storage structures. Sitophilus zeamais was occurred with a dominant mean number 120, 115 & 116 in Asosa, west Gojam & Hawasa areas, respectively. High mean 31.84% of grains damaged was recorded in the sample collected from Hawasa whereas, low mean 6.03% in the sample collected from Buno Bedele areas. High mean 18.00% of weight losses was recorded in the samples collected from Hawasa. The majority 64% of the surveyed farmers stored their grains for more than eight months. The mean number of weevils, weight loss and grain damage showed an increasing trend as the storage periods increased because of most of the farmers stored their maize with husk and/or unshelled in the house; store with cobs in bare ground which favors moisture development and temperature increment in the store. From this survey, it can be concluded that most of the surveyed farmers used traditional storage structures, stored their grains either shelled or unshelled, heap with stalk in the field for a longer period and used insecticides for the control maize weevils. These insecticides have harmful effect on the environment and human health. Therefore, uses of hermetic storage technology can be suggested to the farmers for, reducing weight loss, grains damage, use of insecticides and providing appropriate grains quality.

Introduction

Maize (Zea mays L.) is one of the most important cereals crop in the world both as food for man and feed for animals. It is also known as queen of cereals because of very high yield potential [1]. According to [2], the crop ranks first in total production area and yield per hectare. it has been selected as one of the strategic commodities that satisfy the food self-sufficiency of the country to feed the fast-growing population [3]. However, maize production and yield in Ethiopia, in particular, and Africa, in general have been highly affected by an array of biotic and abiotic stresses [4]. [5] reported that insect pests are of the major challenging biotic constraints during storage. According to [6], reports lepidopterous stem borers and Coleopterous weevils are the most important field and storage insect pests. While, [7] reports showed post-harvest insect pests are considered as the most important and cause huge of losses in the grains (30%–40%) (Boxall, 2002). Insect pests causes the losses up to 5–10% in the temperate zone and 20–30% in the tropical zone of stored grains and grain products (Nakakita, 1998). However [8] explained the post-harvest losses due to insect pest infestations was a major problem concerning among smallholder farmers who practice traditional storage structures. Likewise [9] explained that huge number of pathogenic mycoflora infecting and infesting grain maize and caused a combined worldwide annual loss of 9.4%. To combat the problems of storage insect pest's, various strategies have been used [10,11], but chemical applications remain the key method for pest management with multiple side effects on non-target insects [12,13]. However, indiscriminate chemical applications boost population dynamics [14,15] and lead to insecticide resistance in insect pests [16,17]. Thus,

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inspection, sampling and monitoring of grain stores provide baseline information that is useful in identifying and managing problems associated with grain storage, particularly insect pest infestations. Thus, generating of information from this research can be useful in assessing the absolute importance of loss-causing factors such as temperature, relative humidity, insect pests and the effect of storage structures on grains quality and quantity. Therefore, the objective of this research is: To assess storage insect pests, loss causing factors, effect storage structures and to assess post-harvest losses due to insect infestation.

Materials and methods

Survey areas and sample collection methods

The survey areas were including the selected regions, zones, woredas and kebele's depend on their potential in maize production and selection of farmers was made together with woreda agricultural experts. Its coverers four major maize producing regional states; namely, Amhara, South Nations, Nationalities and Peoples (SNNP), Oromia and Tigray regions. A total of 280 respondent farmers were interviewed in the four regions as the vast majority of maize comes from there. The survey was conducted for three years from in 2018 to 2020 cropping seasons in four regions, Amahara, Oromia, SNNP and Beneshangul Gumuz and Covered seven zones, Asosa, East wollega, W/Wollega, B/Bedele, Hawasa and W/Shawa (Figure 1). Structured questionnaires were administered through personal interviews to obtain primary and other information from farmers. The sample was collected from each of the agroecological areas through the administered questionaries. Formal and local languages that were understood by the farmers were used. Questions asked included demographics, target crop production and storage practices, storage structures, loss incurred after storage, use of stored maize and marketing of the maize. 250 gm of grain maize was sampled from each of the sampling areas. The necessary data (GPS reading, temperature, RH, storage duration, storage method and pest conditions) was collected together with samples (Figure 1). The research design used included observation, assessment and laboratory examination.

Data to be collected

Storage temperature and relative humidity: The temperature and relative humdity of the internal and external environment of the storage was measured at an interval of every week by using portable digital thermo-hygrometer (Hanna, HI8564) and measurement was done in the afternoon 3.00 p.m. in the day (to reduce variations) and at the time three data was taken and its average was recorded. Measurements were taken from the center, side and top portion of the storage according to [18].

Identification of major insect pest: 250 g. of sample was taken from each of the storage for the laboratory insect identification. The grain was sieved through 2 mm mesh sieve (to remove dead and alive insects from the sample taken and to left the grain on the sieve) as method used by [19]. The

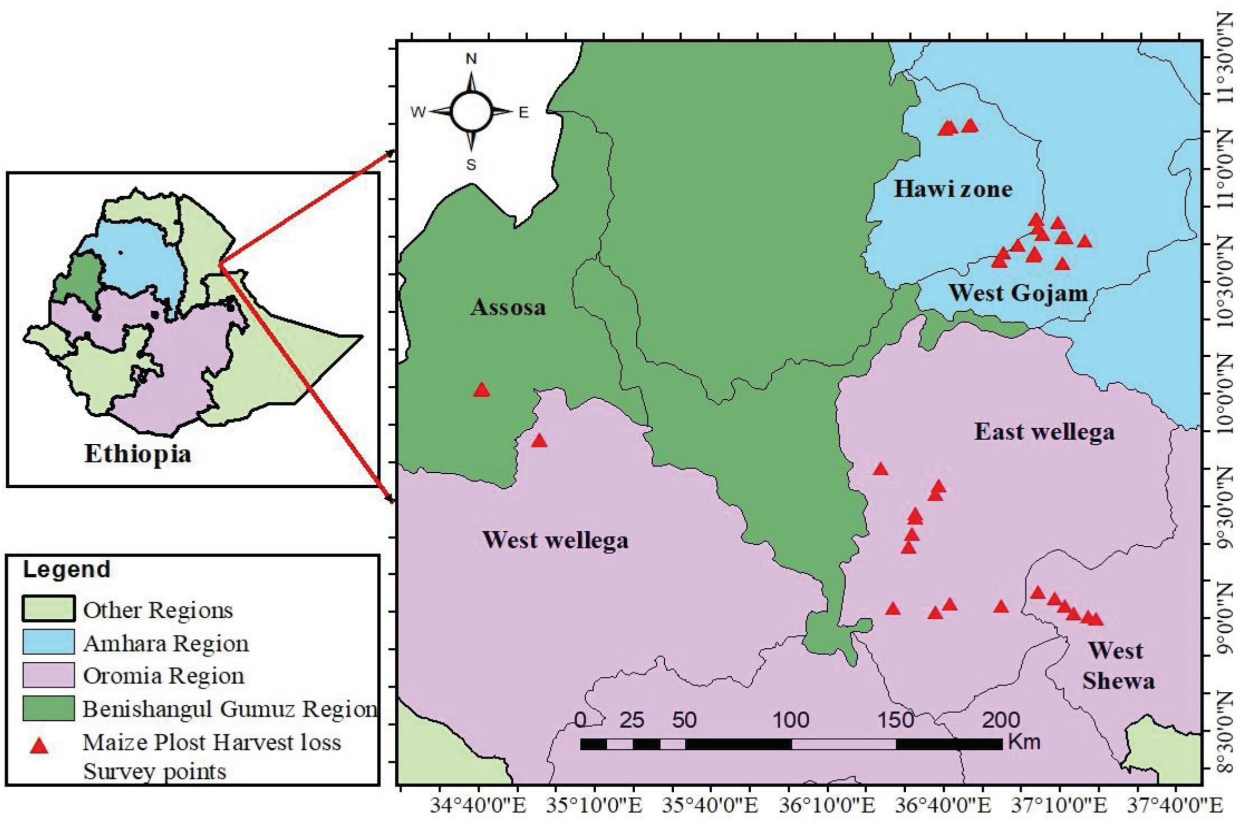

Figure 1: Shows map of maize post-harvest assessment areas of Ethiopia.

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collected insects were identified using specimen collection of the entomology section of Ambo Agricultural Research Center. Both live and dead insect were isolated by using hand lens magnification methods, counted and removed using procedure outlined by entomology department, Bako National Maize Research Center.

Assessment of grain damaged: Insect damage was recorded by the count and weighing method. Each five hundred (500g) grains were taken from initial to last storage periods and from each of the storage types and the number of insect damaged and un-damaged grain were obtained using a hand lens by searching for the presence of hole on the seeds. The percentage of insect damaged grains was calculated according to the methods used by [20] as follows:

$$\text{Insect damaged grain (\%)} = \frac{\text{Number of insect damaged grain}}{\text{Total number of grain}} \times 100$$

Grain weight loss: Weight loss was determined by using a known volume of measuring container and initially the grain was filled into the container and the weight was recorded. The grains were filled till over flow its edge and leveled with scraper. Then grain weight loss was determined through each period of data collection during the study. The weight loss was determined by subtracting from initial period weight at each successive two months interval of sample taken according to the methods used by [21]. Then, the percentage weight loss was calculated as follows:

$$\text{Weight loss (\%)} = \frac{\text{Initial weight-weight of sample taken at any time}}{\text{Initial weight}} \times 100$$

Germination Test: Standard germination tests for control and treated seeds were carried out according to the International Seed Testing Association [22] procedures to evaluate the effect of each treatment on seed germination capacity. 30 seeds were kept in petri-dishes lined on filter paper moistened with distilled water until it was moistened and done in three replications (30 seeds per petri-dishes) and incubated at room temperature (25^{o}c) for 5 to 7 days. The germinated seeds were counted visually up on appearance of radicle and/or plumule and percentage germination was calculated as follows: -

$$\text{Germination}(\%) = \frac{\text{No. of germinated seeds}}{\text{Total No. of seeds soaked in each petri} - \text{dish}} \text{X}100$$

Results and discussions

Demography of the respondent and methods of grains threshing/shelling

The majority of the respondent's farmers were male (84.64%) and 15.36% (n = 280) are female. Among the responded farmers 35% and 16% had primary school and secondary school, respectively. None of the respondents had received a diploma. 49% of the interviewed farmers said that they had no education. The usual methods of threshing/shelling under small-scale farmers' conditions were: (1) manually using hands; (2) manually beating with sticks; (3) few farmers shelling with combiners and (4) at times pounding with mortar and pestle. With the exception of shelling of maize by hand (stripping with fingers, rubbing two cobs against each other, beating cobs or bagged cobs with sticks), such traditional practices cause much loss to the grain's physical quality, scattering of grains out of the threshing floor, and contamination with waste of broken cobs and chaff.

Assessment of postharvest loss factors

A number of factors caused post-harvest loss of grains in the post-production system. These factors are living organisms like fungi, viruses, insects, bacteria, nematodes, chemical and biochemical, mechanical, environmental, and socioeconomic factors. Among the living organisms, insects, mites, rodents, thief birds, ape, monkeys and fungi are the major field and storage pests of the areas. Losses that are caused by pests can be qualitative and quantitative nature, as food is consumed, damaged, or contaminated, especially during the storage period. A number of pathogenic fungi also infecting the grains when the stored grains moisture content was above recommended and some of these pathogens producing mycotoxins that can be harmful to humans and animals.

Maize storage in Ethiopia

Almost all, 98% of the surveyed farmers used traditional storage structures. These traditional storages structures are gombisa (gotera), gumbi, polythene sacks with different size (50 and 100 kg), woven sacks and a few hangs over the tree. The farmers stored their grain maize in shelled and unshelled with cobs. A few of them heap with stalk for two to four months without shelling (Figure 2 B). According to [23], survey data in Ethiopia, farmers store their grain maize in polypropylene or jute bags of 50 or 100 kg capacity after shelling and winnowing. Although Gotera is normally made from wood and plastered with mud and cow dung, farmers in Alamata woreda use stones to build their gotera. However [24] reports different forms of traditional storage structures, generally made of locally available materials such as bamboo split, wooden walls, mud, and thatched grass roofs. In different parts of Africa smallholder farmers uses different storage structure to store their grain.

Likewise [25] indicated that the majority of farmers in Jimma zone (more than 97%) stored their grain in traditional storage that couldn't protect the stored grain from deterioration. Most of the traditional storage structures used by the farmers favors the infestation of the stored grain maize and cause huge

Figure 2: Storage grain structures. A = cobs in gotera, B = stalk in the field, C = cobs on bed, D = shelled in sacks, E = husk on net, F = unshelled cobs in sacks.

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damaged of the grains at the fields and in storage (Figure 4). Similarly, the maize stored with cobs were infested by termites. Not only for the infestation of insect pests but also favors the development mould which develop mycotoxin in the grains and cause a harmful healthy problem and reduces quality and quantity and made grains unfit for consumptions.

Length of storage of grains

In average, 64% (n = 280) of the respondents stored their grains for 1 to 8 months, 20% of them stored for nine to ten months and 13.33% for eleven to twelve months [26] repocrted that the small-scale farmers retain 60 to 90% of the total grain produced for subsistence and store it for 6 to 12 months in Ethiopia. Since the maize grains have low angle of repose it develops temperature and moistures as stored on over heaped for longer periods and imposes the farmer a second-round insecticides application for the control weevils as the weevils newly developed after the application of three months. This costs to the farmers, reduces quality, increases weight losses, grains damage and also leave the residual effect on the grains which was a healthy problem to the human beings after eating [27] explained that grain is often not stored for more than eight months due to poor storage techniques, and inadequate pest management systems in Ethiopia [28] reports showed in Ethiopia, most of the farmers store their grain in traditional methods; which is poorly constructed with locally available materials and cannot protect stored grains from abiotic and biotic agents such as insect pests and fungal diseases. Furthermore, the poor hygiene of traditional grain storage in Ethiopia favors infestation of insect pests and rodents.

Identification of storage insect pests

Seven (7) weevil species *Sitophilu oryzae,Catharanthus pusillus, Sitophilus zeamais, Rhyzopertha dominica, Sitophilus granarius (L.), Tribolium castaneum and Sitotroga cerealella* were identified in the laboratory from the surveyed samples (Table 1). Among the species *R. dominica spp.* occurred with low mean number in all the surveyed areas. *S. zeamais* occurred with maximum mean number 120, 116 & 115 in Hawasa, west Gojam & Asosa, respectively [29]. reports showed *S. zeamais* was recorded with higher mean number of 69.98, while *Sitophilus cerealella* and *Sitophilus oryzae* occurred with a low mean number of 11.26 and 9.09, respectively. However [30] identified different storage insect pests such as *Tribolium castaneum, Rhyzopertha dominica, Sitophilus zeamais and Lasioderma serricorne*, *Plodia interpunctella, Sitotroga cerealella and Corcyra cephalonica* in his survey. Similarly [31] indicated that maize weevil (*Sitophilus zeamais*), *Sitotroga cereallela* "and" the lesser grain weevil (*Sitophilus oryzae*), and *Callosobruchus* spp. for grain legumes are the major of storage insect pests of cereal grains in Ethiopia. Likewise [32] reported

Figure 3: Weevil species identified from the samples in the laboratory.

Table 1: Weevil species identified from the surveyed samples in the laboratory.

No.	Scientific name	Assosa	W/ wollega	E/ wollega	B/ dedele	W/ gojjam	Hawwi	Hawasa
1	*S. oryzae*	2	5	12	65	17	0	31
2	*C. pusillus*	3	0	0	0	0	0	10
3	*S. zeamais*	115	18	20	19	116	30	120
4	*R. dominica*	0	0	0	1	0	0	0
5	*S. granarius*	4	1	4	0	8	4	94
6	*T. castaneum*	6	4	6	4	2	0	75
7	*S. cerealella*	20	4	39	11	14	0	55

Figure 4: Visual scores and observation of damaged grains.

that *Sitophilus zeamais, S. oryzae, Sitotroga cereallela, Tribolium spp. and Ephestia cautella* are the main insect pest of stored grains maize and other cereals in Ethiopia. This is due to most of the farmers in the areas kept their maize heap with stalks on the farm and removed the husk after two to four months this favors for the development of weevils in the fields as well as in the storage period Figure 3.

Control methods used by the farmers

The farmers used cultural and chemical control methods. Cultural control methods are cleaning two to three times their storage per a year, sanitation, dry the grains properly and kept aerated the storage. Few 7% of the farmers used smoke by hanging the cobs on the roof for the seeds. Likewise [33] reported that in Nigeria, between 3.6 and 12% of the farmers used smoke to protect their maize and afflation levels decreased when smoke was used to protect maize. Similarly [34] reported that effectiveness of hanging maize above fire against insect damage and diseases. Almost 80% of the farmers in the surveyed areas used celphox and phosphotoxin fumigants insecticides. A few of them 10 to 13% used emulsion malathion and malathion dust and mographos fumigants tablets in their storage.

Damaged grains, weight loss, germination and farmer's perception of losses

The survey data indicated that high mean 31.84% of grains damaged was recorded in the sample collected from in Hawasa whereas, low mean 6.03% in the sample collected from Buno Bedele areas, respectively. Also, maximum weight loss 18% was recorded in the sample collected from Hawasa. According to visual score during the survey heavy infestation of insect pest grain damage was up to 30 to 100% in sever causes when the farmers not used insecticides and store for three to four months (Figure 4). This is due to heavy infestation of the insect pests in the areas because of the farmers of in the area were

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stored their maize with husk either in sack or without sack in the house. Also [35] reported that 0.2%–11.8% weight loss due to insect infestation in maize after 6 months of storage in traditional granaries in Togo and 3.2, 4.8, 6.8, 7.2 and 8.2% for PICS bag, barns, polypropylene bag and jute sack. Likewise [36] reports showed that a crop loss of 16.4 in Bako, 16.1% in Awassa and up to 17.3% in the Keffa and Illubabor areas due to S. zeamais and S. cereallela. However [37] explained that post-harvest losses of stored grains maize in traditional storage practice was up to 20-30% in developing countries, mostly due storage insect pests and grain moulds [38] assessed a loss of grain up to 59.5% after storage of three months in traditional storage structures (polypropylene bags). Whereas [39] reports grain damage ranged between 11% and 100% and weight loss between 2.9% and 20% of stored maize for storage periods of 2-12 months in Ethiopia. Moreover [40] reports showed that weight losses stored grain maize estimated up to 34 to 40% and 10 to 20%, for P. truncatus and S. zeamais, respectively, after 3 months of on the farm storage.

Maximum mean germination percentage 85% were recorded in the samples collected from Asosa whereas, minimum mean germination 51.67% was observed in the samples collected from Hawas areas (Figure 5). This due to the grains were infested by *S. cereallela* species which infest the grains embryo and made ungerminated [41] reports showed germination of stored maize in the uncontrolled warehouse was declined from 87-99% to 50–80% after eight months of storage in South Africa. The respondent farmers perceptions of grains damaged and weight loss were 20.22 and 16.50% in west Shewa and Hawassa, due to rodent, weevil's infestation, sometimes hens tear the sack and combined effect of damage. The finding is supported by [42] whom survey results indicated the majority of the respondent farmers considered the damage by storage and field rodents to be severe, while larger proportion of them (21.7% for storage rodents and 29.29% for field rodents) rated the effect as moderately sever.

Conclusion and recommendation

Most of the surveyed farmers 98% were used traditional storage structures made of local materials which was not protect their grain from insect infestation. Seven weevil species were identified from the collected samples. *Sitophilus zeamais* was the dominant species occurred with heavy infestation in the sample collected from Asosa, west Gojam & Hawasa. The mean number of weevil species, percentage of weight loss and grains damage showed an increasing trend as the storage periods increased because most of the farmers stored their maize with husk and/or unshelled in the house; store with cobs in bare ground which favors moisture development and temperature increment in the stored maize. The farmers used insecticides and used the stored grains after three months of application by washing the grains for consumption. Since the grains were alive the residual effect left in the grains causes harmful effect on human health. Therefore, uses of hermetic storage technology can be advised to the farmers for reducing germination losses, grains damage, providing appropriate grains quality and reduces uses of insecticides. Also, using of hermetic storage technologies are more advisable for the maize producing farmers. Since maize is strategic crop for food self-sufficient of the country multidisciplinary works is needed in order to reduce post-harvest losses. Additional work is encouraged to examine the quality of the grains stored for more than one year; for healthy aspect of the farmers due to mycotoxin contamination and residual effects.

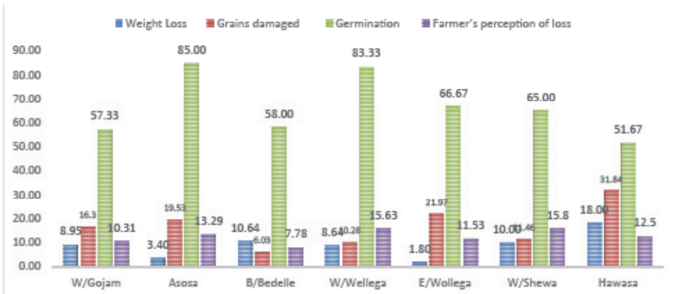

Figure 5: Weight loss, Damaged grains and Germination percentage.

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References

1. Nand V (2015) Effect of spacing and fertility levels on protein content and yield of hybrid and composite maize (Zea mays L.) grown in rabi season. Journal of Agriculture and Veterinary Science 8: 26-31. Link: https://bit.ly/3tLtLaw

2. CSA (Central Statistical Agency). Agricultural Sample Survey Report on Area and Production of Crops (Private Peasant Holding, Meher Season). (2007). Statistical Bulletin, No. 388, Addis Ababa, Ethiopia.

3. Girma D, Tadele T, Abraham T (2008) Importance of husk covering on field infestation of maize by Sitophilus zeamais Motsch (Coleoptera:Curculionidea) at Bako, Western Ethiopia. African Journal of Biotechnology 7: 3777-3782. Link:https://bit.ly/3au5jTB

4. Tefera T, Mugo S, Likhayo P (2011) Effects of insect population density and storage time on grain damage and weight loss in maize due to the maize weevil Sitophilus zeamais and the larger grain borer Prostephanus truncates. African Journal of Agricultural 6: 2249-2254. Link:https://bit.ly/3dK2Q9H

5. Ali RH, Mahdi MR, Ali B, Hojjatollah S (2007) Mycoflora of maize harvested from Iran and imported maize. Pak J Biol Sci 10: 4432-4437. Link: https://bit.ly/3vgv8yt

6. Hiruy B, Emana G (2018) Insect pests associated to stored maize and their bio rational management options in sub-Sahara Africa. Link: https://bit.ly/3dH3ggE

7. Boxall RA (2002) Damage and loss caused by the larger grain borer prostephanus truncates. Integrated Pest Management Reviews, 7: 105-121. Link:https://bit.ly/3gucvD1

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

9. Mendalis E, Abdeta C, Tesfaye A, Shumeta Z, Jifar H (2007) Farmer's perceptions and management practices of insect pest on stored sorghum in Ethiopia. Crop Protection 26: 1817-1825. Link:https://bit.ly/3efBOpm

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10. Tariq K, Ali A, Davies TE, Naz E, Naz L, et al. (2019) RNA interference-mediated knockdown of voltage-gated sodium channel (MpNav) gene causes mortality in peach-potato aphid, Myzus persicae. Sci Rep 9: 5291. Link: https://bit.ly/3xfLskQ

11. Ullah F, Gul H, Wang X, Ding Q, Said F, et al. (2020c) RNAi-Mediated Knockdown of Chitin Synthase 1 (CHS1) Gene Causes Mortality and Decreased Longevity and Fecundity in Aphis gossypii. Insects 11: 22. Link: https://bit.ly/2RTl1RI

12. Desneux N, Decourtye A, Delpuech JM (2007) The sublethal effects of pesticides on beneficial arthropods. Annu Rev Entomol 52; 81-106. Link: https://bit.ly/3ermBlv

13. Ullah F, Gul H, Desneux N, Tariq K, Ali A, et al. (2019b) Clothianidin-induced sublethal effects and expression changes of vitellogenin and ecdysone receptors genes in the melon aphid, Aphis gossypii. Entomologia Generalis 39: 137-149. Link: https://bit.ly/2Qfurqk

14. Ullah F, Gul H, Desneux N, Gao X, Song D (2019a) Imidacloprid-induced hormesis effects on demographic traits of the melon aphid, Aphis gossypii. Entomologia Generalis 39: 325-337. Link: https://bit.ly/3sEN04h

15. Ullah F, Gul H, Tariq K, Desneux N, Gao X, et al. (2020b) Thiamethoxam induces transgenerational hormesis effects and alteration of genes expression in Aphis gossypii. Pestic Biochem Physiol 165: 104557. Link: https://bit.ly/3auGWoS

16. Gul H, Ullah F, Biondi A, Desneux N, Qian D, et al. (2019) Resistance against clothianidin and associated fitness costs in the chive maggot, Bradysia odoriphaga. Entomologia Generalis 39: 81- 92. Link: https://bit.ly/3sCPdwZ

17. Verga BT, Teren J (2005) Mycotoxin producing fungi and mycotoxins in foods in Hungary. Journal of Acta Alimentaria/Akademiai 267-275.

18. Befikadu D, Waktole S, Solomon A, Geremew B, Sethu MR (2012) "Influence of Agro-ecologies, Traditional Storage Containers and Major Insect Pests on Stored Maize (Zea mays L.) In Selected Woredas of Jimma Zone". Asian Journal of Plant Sciences 11: 226-234. Link: https://bit.ly/3vfiTCd

19. Compton JAF, Sherington J (1999) Rapid assessment methods for stored maize cobs: weight losses due to insect pests. Journal of Stored Products Research 35: 77-87. Link: https://bit.ly/3dF7XYD

20. CGC (Canadian Grain Commission) (2014) Insect Identification and Biology 25.

21. Wambugu PW, Mathenge PW, Auma EO, Rheenen HA (2009) Efficacy of traditional maize (Zea mays L.) seed storage methods in Western Kenya. African Journal of Food Agriculture Nutrition and Development 9: 1110- 1128. Link: https://bit.ly/2QNbKtG

22. Adams JM, Schulter GM (1978) Losses Caused by Insects, Mites and Micro-organisms. In: Postharvest Grain Loss Assessment Methods. Harris K.L. and Lindblad C.G. (eds), New York, American Association of Cereal Chemists 83-95.

23. ISTA 2005 International Rules for Seed Testing: International Seed Testing Association, Bassersdorf, Switzerland. Link:https://bit.ly/32Bl6eP

24. FAO (Food and Agricultural Organization of the United Nations) (2017) FAO (Food and Agriculture Organization of the United Nations). (2017) Postharvest loss assessment of maize, wheat, sorghum and haricot bean.

25. Midega CA, Murage AW, Pittchar JO, Khan ZR (2016) Managing storage pests of maize: Farmers' knowledge, perceptions and practices in western Kenya. Crop Protection 90: 142-149. Link:https://bit.ly/3x8D3zo

26. Kemeru D (2004) Farm level survey on farm tools and implements in Jimma and Iluababor Zones. A research Report, Oromiya Agricultural Research Institute, Jimma Rural Technology Research Center, Oromiya, Ethiopia.

27. Mohammed A, Tadesse A (2018) Review of Major Grains Postharvest Losses in Ethiopia and Customization of a Loss Assessment Methodology. USAID/Ethiopia Agriculture Knowledge, Learning, Documentation and Policy Project, Addis Ababa. Link:https://bit.ly/3gu7tWV

28. Demissie G, Teshome A, Abakemal D, Tadesse A (2008) Cooking oils and Triplex in the control of Sitophilus zeama is motschulsky (Coleoptera: Curculionidae) in farm-stored maize. J Stored Prod Res 44: 173-178. Link:https://bit.ly/2RWCUiv

29. Nezif A, Kumela D, Wakuma B, Debela H, Esayas M, et al. (2020) Impact of Farmers' Storage Practices and Storage Hygiene on Grain Losses in Ethiopia. Food Science and Quality Management 93. Link: https://bit.ly/3gyCgSu

30. Waktole S, Amsalu A (2012) Storage pests of maize and their status in Jimma Zone, Ethiopia. African Journal of Agricultural Research 7: 4056-4060. Link:https://bit.ly/3gHNjcn

31. Utono IM (2013) Assessment of grain loss due to insect pest during storage for small-scale farmers of Kebbi. IOSR Journal of Agriculture and Veterinary Science (IOSR-JAVS) 3: 38-50. Link: https://bit.ly/3xfKAN6

32. Tefera T, Kanampiu F, De Groote H, Hellin J, Mugo S (2011) The metal silo: an effective grain storage technology for reducing post-harvest insect and pathogen losses in maize while improving smallholder farmers' food security in developing countries. Crop Prot 30: 240-245. Link: https://bit.ly/3dK1AU1

33. Abraham T (1997) The biology, significance and control of the maize weevil, Sitophilus zeamais Motsch (Coleoptera: Curculionidae) on stored maize. MSc. Thesis. Alemaya University of Agriculture. Ethiopia.

34. Udoh JM, Cardwell KF, Ikotun T (2000) Storage structures and aflatoxin content of maize in five agroecological zones of Nigeria. Journal of Stored Products Research 36: 187-201. Link:https://bit.ly/3gAHmxP

35. Thamaga-Chitja JM, Hendriks SL, Ortmann GF, Green M (2004) Impact of maize storage on rural household food security in Northern Kwazulu-Natal. Journal of Family Ecology and Consumer Sciences 32: 8-15.

36. Deepak K, Prasanta K (2017) Reducing Postharvest Losses during Storage of Grain Crops to Strengthen Food Security in Developing Countries. Foods 6: 18. Link: https://bit.ly/3naJoGb

37. Mekuria T (1994) Status of maize storage insect pests in the south western Ethiopia. A paper presented in the second annual conference of Crop Protection Society of Ethiopia. April 26-27, Addis Ababa, Ethiopia.

38. Costa SJ (2014) Reducing food losses in sub-Saharan Africa (Improving post-harvest management and storage technologies of smallholder farmers). UN World Food Programme, Kampala. Link: https://bit.ly/32BpzhF

39. AGRA (Alliance for a Green Revolution in Africa) (2013) Establishing the status of post-harvest losses and storage for major staple crops in eleven African countries (Phase I). AGRA: Nairobi, Kenya.

40. Boxall RA (2002) Damage and loss caused by the larger grain borer Prostephanus truncatus. Integr Pest Manage Rev 7: 105-121. Link: https://bit.ly/2QNqHw5

41. Tekrony DM, Shande T, Rucker M, Egli DB (2005) Effect of seed shape on corn germination and vigour during warehouse and controlled environmental storage. Seed Science and Technology 33: 185–197. Link: https://bit.ly/3sELEGJ

42. Yibrah B, Dereje A (2015) Report On: Postharvest Loss Assessment Survey-in Ethiopia. Baseline Information on Maize (Zea mays L.) Postharvest Loss Assessment. Link:https://bit.ly/3tGYpSs

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