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Varietal screening for resistance against field and storage crop pests: An implication for Ethiopian crop variety development

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Food security in developing countries like Ethiopia has been a challenge for many years due to pre and post-harvest losses of agricultural products which are caused by different biotic and abiotic factors. Grain losses from pest infestation prior to harvest and during storage are a serious problem, particularly in developing countries like Ethiopia. More than 70% insect pests have been identified; they attack stored grains among which beetles and moths are the most important. The overall quantitative and qualitative damages caused by these insect pests are estimated at 30 to 40% annually. To minimize these damages, development of less susceptible germplasms, cultivars and varieties which are an eco-friendly and economically feasible management options has been encouraged by many scholars since the development of modern breeding technologies. Thus, resistant varieties can have a tremendous impact on sustainable crop production to ensure future food security. This paper provides a comprehensive literature review of varietal screening research for field and storage pests associated with the major food and export crops with particular emphasis on Ethiopia.

Key words: Insect, screening, biotic stress, breeding, grain pests.

INTRODUCTION

Events of biotic stresses such as, potato blight Ireland, maize leaf blight in USA, coffee in Brazil and Bengal famine were mentioned as historical significance cases in the world (Hussain, 2015; Singh et al., 2017). These events had devastated food production which resulted in a number of human population's deaths and migration to avoid famine. These stresses continue to cause an important risk to agricultural production and productivity even though different research and development activities have been implemented to investigate the host-plant interaction and availing effective methods to control it (Lucas, 2011). In this case both insects and disease are among the important biotic factors that cause significant losses in yield and quality which lead to many types of damages. In many agro-ecological zones, the crop production and productivity has been also threatened due

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to the appearance of new races and biotypes of pathogen and insect (Sanghera et al., 2011). Significant yield losses from plant diseases such as wilt, phyllody, powdery mildew, blight and leaf spots in addition to insect pest such as capsule borer, and sucking pests like mites and thrips have been reported (Abd-El-Ghany et al., 1974; Jyothi et al., 2011). Metabolic stresses on crop plants as well as physical damage to commodities due to insects, diseases, nematodes, larger animals such as rodents, weeds, etc. are factors reducing crop productivity and grain quality. However, the world food supply can increase through; increasing the crop acreages, fertilization, and irrigation and improving the use of improved varieties, cultivation methods and improved crop protection strategies which may also cause different genetic and environmental impacts on plant product (Yazici and Bilir, 2017).

Ethiopia has a wide variety of favorable climates and soil types where different crops can be grown for domestic consumption as well as for export. The major crops produced in Ethiopia constitute cereals, grain legumes, and oilseeds. These crops are produced mostly during the main growing season which extends from June to October. Some crops are also planted during the short rains (March to May). Though crop production in Ethiopia contributes a major share to the agricultural sector, it has suffered for years from several factors, including the use of traditional farm implements, subsistence farming system, limited use of modern farm inputs, drought and pre- and post-harvest pests and other unlimited challenges that bring the food security scenario of the country into question and remains a critical issue for many households.

To alleviate the biotic stress on crop plants, various genomics research and completion of the genome sequence of different crops has been implemented which enables a precise mapping of different genes through linkage to DNA markers. Genes linked to markers could be resistant to or tolerant to different stress including blast, bacterial blight, virus diseases, brown planthopper (*Nilaparvata lugens*), drought, submergence, salinity, and temperature (Jena and Mackill 2008; Ashraf and Foolad 2013).

Hence, the linked genes which are called quantitative trait loci (QTLs) that govern different traits could be identified, as a result, indirect selection techniques can be implemented to ameliorate the breeding efficiency via marker-assisted selection (MAS) (Ashraf and Foolad, 2013). Thus, both conventional and MAS breeding techniques could be combined for testing the presence or absence of these genes in the breeding populations. The development of molecular markers and MAS technology helps to conduct many studies to identify genes or QTLs affecting pest tolerances in many plant species (Simcox et al., 1993; Adhikari et al., 2003; Singh et al., 2004; Soundararajan et al., 2004; Chu et al., 2010; Foolad et al., 2012; Shi et al., 2014; Liu et al., 2016; Sorkheh et al., 2016) (Table 1). The study general objective is to review the plant genetic diversity for yield and pest resistance, while the specific objectives are:

(1) Review the varietal screening research approaches against major field and storage pests.
(2) Provide an overview of breeding methods for biotic stress and source of pest resistance.
(3) Assess existing pest management options in Ethiopia.

Crop genetic diversity

Ethiopia is a major of genetic diversity for a number of cultivated crops and their wild relatives (Tanto and Demissie, 2000; Worede et al., 2000), and this diversity can play a major role in enhancing and improving the productivity of the crops through maintaining and enhancing the durability of the crop to diseases, pests, drought, and other stresses. Sorghum, barley, teff, chickpeas, and coffee, which are largely represented in the country by landraces and wild types, are uniquely adapted to local environments (CSA, 2014/2015; Tanto and Demissie, 2000). Hence, maintaining the crop, species and genetic diversity in farmers' field is very important to sustain agricultural production, improve nutrition, and help the ecosystem which is essential for the livelihood of communities, particularly for resource-poor farmers practicing agriculture under low-input conditions on the marginal lands (Worede et al., 2000).

Overview of plant disease and insect pets

Plant disease

More than 800 million people lack adequate food as a result of plant diseases (FAO, 2012; Christou and Twyman, 2004). Field surveys conducted in wheat growing areas of Ethiopia have shown that diseases are the major constrains to wheat production (CSA 2014/15), among these, leaf, stem and stripe rust are the most important with stem rust (*Puccinia graminis tritici*) considered the most destructive due to emergence of race Ug99 (Singh et al., 2011). In 1988, stem rust race Ug99 was first observed in Uganda. According to Singh et al., (2011), seven races of Ug99 ancestry are known and spread to different wheat-growing countries in the eastern African highlands, Zimbabwe, South Africa, Sudan, Yemen, and Iran. The wheat varieties growing in these countries are reported as very susceptible (90%), and then the Ug99 group of races was considered as a major threat to wheat production and food security (Singh et al., 2011).

Plant Insect pests

Nearly 60 insect species are known to feed on crop

Table 1. Identified molecular markers, gene locus and chromosomal locations for pest tolerance in different plant species.

Crop plants	Molecular markers	QTL/genes Locus	Chromosomal location	Pests	Traits governed	References
Rice (*Oryza sativa* L.)	SSR	Est9–RZ337B; RG157–RZ318; RG146–RG345; RG213–Est2; Pgi2–pRD10B; RG773–Est2	7; 2; 1; 6; 6; 7	Brown planthopper (BPH), *Nilaparvata lugens* (Stål) (Homoptera: Delphacidae)	Seedling –resistance; antibiosis, tolerance; tolerance; tolerance; tolerance	Soundararajan et al. (2004)
Bread wheat (*Triticum aestivum*)	SNP	*QYr.osu-5A*	5A	Stripe rust races	Resistance in adult plants to predominant stripe rust races	Liu et al. (2016)
Maize (Zea mays L.	RFLP	Htnl	8	Setospaeria turcica	Resistance	Simcox et al. (1993)
Wheat (*Triticum aestivum* L.)	DArT	*QStb.2A*	2A	*Septoria tritici* blotch (STB)	High level of resistant	-
Wheat (*Triticum aestivum* L.)	microsatellite markers	Stb8	7b	Septoria tritici leaf blotch (STB), caused by the ascomycete Mycosphaerella graminicola	Resistance to STB	Adhikari et al., (2003)

plants among which the pod borers (*Helicoverpa* spp.), leaf miners (*Liriomyza cicerina*), bruchid weevils (*Callosobruchus* spp.), cowpea aphid (*Aphis craccivora*), cutworms (*Agrotis* spp.), and armyworms (*Spodoptera* spp.) are the most important insects reported (Sharma et al., 2007; Li et al., 2015). According to Worku et al. (2012), there are four species of stem borers that infect the maize plant in Ethiopia while in Africa the African stalk borer (*Busseola fusca* Fuller), the spotted stem borer (*Chilo partellus* Swinhoe), the pink stem borer (*Sesamia calamistis* Hampson) and the sugarcane borer (*Eldana saccharina* Walker) are the major insects reported to attack maize (Mailafiya and Degri, 2012). Abate et al., (2015) reported three species of stem borers (*viz*. *B. fusca*, *C. partellus* and *S. calamistis*) which are known to be distributed across maize growing agro-ecologies in Ethiopia though *B. fusca* and *C. partellus* are reported as the most economically important stem borers in Ethiopia (Demissie et al., 2014).

Globally, yield loss from insects have been estimated at 14% for all important crops (Poehlman, 2013), which results from insects sucking cell sap or eating away various plant parts as well as through transmission of various diseases. According to Chaudhry et al. (1989), leaf roller/webber is a serious pest of sesame, which causes 15 to 20% damage to the crop at vegetative stages and 10 to 15% at productive stages. Significant yield losses (50%) were recorded in legumes including faba bean, field pea, chickpea and lentil from some aggressive storage insect pests like *C. chinensis* (*Damte* and Dawd, 2003). Gwinner et al. (1990) and Tabu et al. (2012) reported losses due to storage insect pests particularly due to adzuki bean beetle which are greater in tropical and subtropical regions than in the temperate areas. Reports from Ali and Tibebu (1993) and Tebkew and Mohamed (2006) indicated that the adzuki bean beetle caused losses of up to 50% in chickpea in Ethiopia.

Insect and disease management in Ethiopia

Conditioning of grain by forced air dryers, use of different storage structures, application of botanicals or insecticides and use of resistance varieties are effective in reducing damage from grain storage pests. Among the various cultural methods tested in Ethiopia for storage pest management, solar heating of maize grain placed on a black polyethylene sheet and covered with a translucent plastic sheet for at least five sunny days caused significantly higher (72%) mortality of maize weevil (*S. zeamais*) (Abreham, 2003 & Demissie et al, 2012). Botanical products were also effective for protecting stored grain from insect damage. Treatment with leaves of *Eucalyptus globulus*, *Schinese molle*, *Datura stramonium*, *Phytolacca dodecandra*, and *Lycopersicum esculentum* were observed to cause high adult maize weevil mortality (Abraham, 2003). In Ethiopia, the botanicals Mexican tea powder (*Chenopodium umbrosiodes* L.), triplex and neem seed powder (*Azadirchata indica*) cause high percentage of adult maize weevil mortality, reduced progeny emergence and lower grain damage (Girma et al., 2008a, b). A laboratory experiment to evaluate the use of inert dust, cotton seed and Ethiopian mustard seed oils *(Brassica carinata),* against Angomois grain moth (Sitotroga cereallela) concluded that cotton and

Ethiopian mustard seed oils exhibit strong toxic activity at concentration levels less than or equal to 0.2% (v/w) (Fekadu & Girmay, 2015).

The use of chemical insecticides in the form of sprays, fumigant or dusts against different pests has been common in Ethiopia. In some parts of the country about 70% of the farmers treated their grains with synthetic chemicals (Tadesse 2005).

Resistant crops

Using resistant varieties as component of an integrated pest management is considered as best and cheapest best method to control insect in agricultural production system. Genetic resistance refers to the ability of some genotypes to give higher yields than susceptible varieties at the same initial level of insect attack under similar environmental conditions (Russell, 2013).

Shaheen et al. (2006) stated that improving the genetic resistance of the host plant is considered to be an effective management options for the pets damage on the crops. As an integrated pest management tactic, host-plant resistance entails the intentional use of resistant crop varieties, alone or in combination with other tactics, to reduce the impact of herbivores on crop yield or quality (Stout, 2014). Resistance crops might be found in taxonomic groups that are more or less distantly related to the crop, such as the cultivar itself, commercial cultivars, landraces, wild progenitors, related species and genera (Balconi ET AL., 2012).

A complete resistance was reported in cultivated and germplasm of haricot bean, field pea, cowpea, black gram and chickpea (Keneni et al., 2012) while Dogimont (2010) reported a high level of bruchid resistance from the cultivated rice bean (*Vigna umbellata*). Some accessions of cultivated common bean with moderate levels of resistance to *A. obtectus* and *Z. subfasciatus* were identified by and used in breeding programs to generate partially resistant materials adapted to East African production conditions (Kusolwa, 2007). In stored grains several factors lead to the production of resistance against infestation by storage insect pests, which include the tightness of the glumes in unmilled rice which serve as physical barrier working against penetration by insects; hardness of seeds to make insect penetration more difficult and seed size, as large grain legumes provide more surface area for oviposition and larval development than small-size grains (Chanbang et al., 2008).

Resistant varieties for field crop pests

Since 2005 to 2010, over 200,000 wheat varieties, accessions, and advanced breeding materials were screened for resistance to Ug99 and its derivative races at Njoro, Kenya, and Ethiopia and resistant genotypes were identified (Singh et al., 2011). Screening of 26 sesame breeding lines in Turkey to Fusarium wilt disease indicated, sanliurfa-63189 was the most resistant genotype (Kavak and Boyda, 2006). “Birkan”,Çamdibi, WS-143, WS-313 were classified as resistant. “Birkan”, a recently released cultivar for large seed and high yield was resistant to the *Fusarium* wilt disease (Silme and Cagirgan, 2010). Screening of maize against maize stem borer, Sultan followed by Akbar was found to be the most tolerant varieties. El-Bramawy and Wahid (2009) reported sesame genotypes S2 and H4, originated from a selection and hybridization respectively, seem to be stable for wilt disease. These authors also indicated the sesame genotypes such as Mutants 8, U N. A 130, H 1 and S1 kept their resistance classes during the two successive seasons. A research conducted to test genetic resistance of maize inbreed lines against northern corn leaf blight (NCLB), southern corn leaf blight (SCLB), *Curvularia* leaf spot (CLS), gray leaf spot (GLS), common rust, and southern rust indicated that, five lines, 313, Chang 7-2, Qi 319, Qi 318, and Shen 137 were resistant to the five diseases tested while lines OH 43, X178, Qi 318, Za C546, 8065, 81565, 313, CAL99, and B 151 were found resistant or moderately resistant to southern rust (Wang et al., 2014).

Resistant varieties for storage pests

Screening against *S. zeamais* showed that out of the thirteen maize varieties, only one BHQP-542 was resistant (Abebe et al., 2009). Experiments conducted on hybrid maize varieties for maize weevil and large grain borer identified six resistant hybrids (CKPH08037, CKPH08041, CKPH08012, CKPH08024 and CKPH08026) and two moderately resistant hybrids (CKPH08038, CKPH09004) to the large grain borer (Teffera *et al* 2013). Maize genotypes, resistant to the maize weevil included AW8047, INT-A, Pob-62TLWF-QPM, TUXEPENO C6, USB, Golden Valley (Demissie et al., 2012).

Similarly, Demmisie et al. (2013b) reported one quality protein maize (QPM) inbred line (CML-142) as resistant and three (CML-144/144-7-b (F2)-4-2-1-1-1-1-1, POOL 15QPFS-693-B-2-B-#-B-B-B-# and CML-149) QPM lines were moderately resistant to *Sitophilus zeamais.* Resistant against Sitotroga *cerealella* among the twelve wheat genotypes based on progeny emergency showed genotypes IBW-97103 and IBW-97083 had significantly lower grain damage and IBW-97103 had significantly lower weight loss compared to all other genotypes. Characterization of 130 chickpea genotypes by Keneni et al. (2011) in Ethiopia indicated one genotype exhibited complete resistance to adzuki bean beetle; whereas, improved genotypes showed considerably higher susceptibility particularly, in terms of number of eggs per female, adults emerged and seed weight loss. Eker et al. (2018), from their laboratory experiment reported that, Desi type chickpea exhibits better resistance characteristic to *callosobruchus chinensis* than the Kabuli type which means the Kabuli accessions in which their seeds are characterized by creamy colored, smooth surface and ram's shape are more preferred by the insect than the Desi type. Demissie et al. (2014) screened maize varieties to sitotroga cerealla under no-choice test method showed that pratap makka-5 was found the most resistance varieties. Tefera and his colleagues in 2013 screened 25 maize hybrids against S. zeamais and one hybrid, CKPH08004, showed resistance.

Methods of breeding for resistance crops

The traditional approach to the development and use of resistant varieties in integrated pest management involves four steps: screening (evaluation of crop germplasm for resistant genotypes), categorization (assignment of resistance phenomena to the categories of antibiosis, antixenosis, and tolerance), breeding (introduction of genes responsible for resistance into agronomically acceptable backgrounds), and implementation (integration of resistant varieties into management programmes) (Stout, 2014). Singh et al. (2002) indicated that backcross breeding technique is the most appropriate breeding method for transferring the cytoplasm from one parent to another using the parent from which the cytoplasm is to be transferred as the female if the seed resistance is under cytoplasmic gene effects. Jena and Mackill (2008) reported that Marker-assisted backcross breeding has been used to effectively integrate major genes or quantitative trait loci with large effect into widely grown varieties and pyramiding the different resistance genes using MAS provides opportunities to breeders to develop broad-spectrum resistance for diseases and insects. Depending on the mode of inheritance and the number of genes controlling resistance under a given condition, the different selection methods (that is, mass, bulk, pedigree and backcross methods, *etc.* or their modifications) can be applied. Generally, developing farmers' knowledge and their existing practices on cultivars resistant to diseases and pets can help farmers to adopt new cultivars as easy as possible.

Conclusions

Plants at field and harvested produce need to be growing healthy and stored safely and scientifically in order to maintain its original quality while avoiding any spoilage by storage pests. In this case, effective management practice could have positive consequences for poverty alleviation, food security, nutrition status, and increases household income for the smallholder farmer in developing countries. Appropriate insecticide use will continue to play an important role in insect control, but nonchemical alternatives remain a safer and more environmentally beneficial approach for tropical farmers. Improved crop production and quality through breeding to screen resistant varieties have tremendous impact for sustainable crop production in the world in general and in Ethiopia in particular. Many varieties of the same grain species appear to be less suitable than others for insect development, and are often described as being "resistant" (or in fact, less susceptible) to insect attack. The development of insect resistant plants is therefore an important objective of plant breeding strategies with relevant implications for both farmers and the seed and agrochemical industries. The conventional approach of germplasm screening against major biotic stresses enables one to identify sources of biotic stress tolerance genes, which can then be utilized in the breeding programs through MAS. Different scholars indicated that genetic sources of pest tolerance have been reported in different crop species, which could be used further for different breeding purposes. The development of molecular markers and mapping technology enables researchers to identify genes or QTLs of interest traits and transfer from unadapted genetic backgrounds into modern cultivars via the process of MAS. To ease breeding for resistance to the major biotic stresses in Ethiopia, rapid and well–designed introgression of specific biotic stress tolerance genes into cultivars, germplasm, introduced and developed improved varieties can ensure pronounced genetic gain. Ways of introducing and integrating recent advances in biotechnology with the conventional breeding approaches should be researched and implemented.

CONFLICT OF INTERESTS

The author has not declared any conflict of interests.

REFERENCES

Abd-El-Ghany AK, Seoud MB, Azab MW, Mahmoud BK, El-Alfy KAA, Abd-El-Gwad MA (1974).Tests with different varieties and strains of sesame for resistance to root rot and wilt diseases. Agricultural Research Review 52:75-83.

Abate T, Shiferaw B, Menkir A, Wegary D, Kebede Y, Tesfaye K, Keno T (2015). Factors that transformed maize productivity in Ethiopia. Food Security 7(5):965-981.

Abebe F, Tefera T, Mugo S, Beyene Y, Vidal S (2009). Resistance of maize varieties to the maize weevil *Sitophilus zeamais* (Motsch.) (Coleoptera: Curculionidae). African Journal of Biotechnology 8(21).

Abraham T (2003). Studies on some non-chemical insect pest management options on farm-stored maize in Ethiopia. PhD. thesis, School of Graduate Studies, Giessen University, Germany.

Adhikari TB, Anderson JM, Goodwi SB (2003). Identification and molecular mapping of a gene in wheat conferring resistance to Mycosphaerella graminicola. American Phytopathological Society, Phytopathology 93(9):1158-1164.

Ashraf M, Foolad MR (2013). Crop breeding for salt tolerance in the era of molecular markers and marker-assisted selection. Plant Breeding 132(1):10-20.

Balconi C, Stevanato P, Motto M, Biancardi E (2012). Breeding for biotic stress resistance/tolerance in plants. In Crop Production for Agricultural Improvement, Springer Netherlands pp. 57 -114.

Chanbang Y, Arthur FH, Wilde GE, Throne JE, Subramanyam BH (2008). Methodology for assessing rice varieties for resistance to the lesser grain borer, Rhyzopertha dominica. Journal of insect science 8(16):1-5.

Chaudhry AH, Oad BR, Mehring K (1989). Highlights of improvement research on oilseed crops in Sndh. Oilseed Section, Agricultural Research Institute Tandojam pp. 15-17.

Chu CG, Chao S, Friesen TL, Faris JD, Zhong S, Xu SS (2010). Identification of novel tan spot resistance QTLs using an SSR-based linkage map of tetraploid wheat. Molecular Breeding 25(2):327-338.

CSA-Central Statistical Agency (2015). Agricultural Sampling Survey, volume VI, Report on area and production of major Crops (2014/2015).

Damte T, Dawd M (2003). Chickpea, lentil and grass pea insect pest research in Ethiopia: A review. In Food and Forage Legumes of Ethiopia: Progress and Prospects. Proceedings of a Workshop on Food and Forage Legumes pp. 22-26.

Demissie G, Bitew T, Berhanu T, Teshome K, Tende R, Tefera T, Mugo S (2014), February). Response of the popular maize cultivars in Ethiopia to stem borers and post-harvest pests. In Abstract. A paper presented on End-of IRMA III Conference ''Consolidating Experiences from IRMA I, II and III: Achievements, Lessons and Prospects'' IRMA Project Document (17):23-27.

Demissie G, Admassu S, Getu E, Azerefegn F (2012). Review of the Past Decade's (2001-2011) Research on Pre-Harvest Insect Pests of Maize in Ethiopia. In: M. Worku, Twumasi-Afriyie, S., Wolde, L., Tadesse, B., Demisie G., Bogale, G., Wegary, D. and Prasanna, B.M. (Ed.), Meeting the Challenges of Global Climate Change and Food Security through Innovative Maize Research, Addis Ababa P 166.

Dogimont C, Bendahmane A, Chovelon V, Boissot N (2010). Host plant resistance to aphids in cultivated crops: genetic and molecular bases, and interactions with aphid populations. Comptes Rendus Biologies 333(6-7):566-573.

Eker T, Erler F, Adak A, Imrek B, Guven H, Tosun H S, Ikten C (2018). Screening of chickpea accessions for resistance against the pulse beetle, *Callosobruchus chinensis* L. (*Coleoptera*: Bruchidae). Journal of Stored Products Research 76:51-57.

El-Bramawy MA, Wahid OA (2009). Evaluation of resistance of selected sesame (*Sesamum indicum*) genotypes to *Fusarium wilt* disease caused by *Fusarium oxysporum* f. sp. sesami. Tuni. Journal of Plant Protection 4(1):29-39.

Food and Agriculture Organization (FAO) (2012). Global pact against plant pests marks 60 years in action. Food and Agriculture Organization of the United Nations (FAO), Rome. www.fao.org/news/story/en/item/131114/icode/

Fekadu G, Girmay B (2015). Laboratory Evaluation of Cotton seed, (Gossypium hirsutum Hirstum) and Ethioian mustard Brasica carinata) seed oils against Angomois grain moth, *Sitotroga cereallela* (LEPIDOPTERA: *GELECHIIDAE*) Oliver in Dilla condition. International Journal of Current Research 7(11):22080-22085.

Foolad MR, Panthee DR (2012). Marker-assisted selection in tomato breeding. Critical Reviews in Plant Sciences 31(2):93-123.

Girma D, Teshom A, Abake mal D, Tadesse A (2008a). Cooking oils and "triplex" in the control of *Sitophilus zeamais* Motschulsky (Coleoptera: Curculionidae) in farm-stored maize. Journal of Stored Products Research 44:173-178.

Girma D, Tefera T, Tadesse A (2008b). Management of the maize weevil *Sitophilus zeamais* Motsch. (Coleoptera: Curculionidae) using Botanical Insecticides on three maize genotypes. Pest Management Journal of Ethiopia 12:49-58.

Gwinner J, Harnisch R, Mück O (1990). Manual on the prevention of post-harvest grain losses. Post-harvest Project, Pickhuben, Hamburg, FRG.

Hussain B (2015). Modernization in plant breeding approaches for improving biotic stress resistance in crop plants. Turkish Journal of Agriculture and Forestry 39(4):515-530.

Jena KK, Mackill DJ (2008). Molecular markers and their use in marker-assisted selection in rice. Crop Science, 48(4):1266-1276.

Jyothi B, Ansari NA, Vijay Y, Anuradha G, Sarkar A, Sudhakar R, Siddiq EA (2011). Assessment of resistance to Fusarium wilt disease in sesame (*Sesamum indicum L.*) germplasm. Australasian Plant Pathology 40(5):471-475.

Kavak H, Boydak E (2006). Screening of the resistance levels of 26 sesame breeding lines to Fusarium wilt disease. Plant Pathology Journal 5:157-160.

Keneni G, Bekele E, Getu, E, Imtiaz M, Dagne K, Assefa F (2012). Genetic Gain for Adzuki Bean Beetle (*Callosobruchus chinensis* L.) Resistance in Ethiopian Chickpea (*Cicer arietinum* L.) Genotypes. East African Journal of Sciences 6(1): 43-54.

Keneni G, Bekele E, Getu, E, Imtiaz M, Damte T, Mulatu B, Dagne K (2011). Breeding food legumes for resistance to storage insect pests: potential and limitations. Sustainability 3(9):1399-1415.

Li H, Rodda M, Gnanasambandam A, Aftab M, Redden R, Hobson K, Rosewarne G, Materne M, Kaur S, Slater AT (2015). Breeding for biotic stress resistance in chickpea: progress and prospects. Euphytica 204(2):257-288.

Liu M, Lei L, Powers C, Liu Z, Campbell KG, Chen X, Yan L (2016). TaXA21-A1 on chromosome 5AL is associated with resistance to multiple pests in wheat. Theoretical and Applied Genetics 129(2):345-355.

Lucas JA (2011). Advances in plant disease and pest management. The Journal of Agricultural Science 149(S1):91-114.

Kusolwa PM (2007). Breeding for bruchid resistance in common bean (Phaseolus vulgaris L.): Interspecific introgression of lectin-like seed proteins from tepary bean (*Phaseolus acutifolius* A. Gray), genetic control and bruchid resistance characterization. Oregon State University. Kusolwa, Paul Mbogo pp. 120-142.

Mailafiya DM, Degri MM (2012). Stem borer's species composition, abundance and infestation on maize and millet in Maiduguri, Nigeria. Archives of phytopathology and plant protection 45(11):1286-1291.

Poehlman JM (2013). Breeding field crops. Springer Science & Business Media. 3rd ed. 451-588.

Russell GE (2013). Plant Breeding for Pest and Disease Resistance: Studies in the agricultural and food sciences. Butterworth-Heinemann.

Sanghera GS, Wan S H., Singh G, Kashyap PL, Singh NB (2011). Designing crop plants for biotic stresses using transgenic approach. Vegetos 24:1-25.

Shaheen FA, Khaliq A, Aslam M (2006). Resistance of chickpea (*Cicer arietinum* L.) cultivars against pulse beetle. Pakistan Journal of Botany 38:1237-1244.

Sharma HC, Gowda CL, Stevenson PC, Ridsdill-Smith TJ, Clement SL, Rao GR, Romeis J, Miles M, El Bouhssini M (2007). Host plant resistance and insect pest management in chickpea. In: Yadav SS, Redden RJ, Chen W, Sharma B (eds) Chickpea breeding and management. CAB International, Wallingford pp. 520-537.

Shi L, Lv X, Weng J, Zhu H, Liu C, Hao Z, Li X (2014). Genetic characterization and linkage disequilibrium mapping of resistance to gray leaf spot in maize (*Zea mays* L.). The crop Journal 2(2-3):132-143.

Silme RS, Cagirgan MI (2010). Screening for resistance to Fusarium wilt in induced mutants and world collection of sesame under intensive management. Turkish Journal of Field Crops 15(1): 89-93.

Simcox KD, Bennetzen J L (1993). The use of molecular markers to study Setosphaeria turcica resistance in maize. Phytopathology 83(12):1326-1330.

Singh BB, Ehlers JD, Sharma B, Freire-Filho FR (2002). Recent progress in cowpea breeding. *Fatokun CA, Tarawali SA, Singh BB, Kormawa PM* pp. 22-40.

Singh R, Mani VP, Koranga KS, Bisht GS, Khandelwal RS, Bhandari P, Pant SK (2004). Identification of additional sources of resistamce to Exserohilum turcicum in maize (*Zea mays* L.). SABRAO Journal of Breeding and Genetics 36:45-47.

Singh RP, Hodson DP, Huerta-Espino J, Jin Y, Bhavani S, Njau, P, Govindan V (2011). The emergence of Ug99 races of the stem rust fungus is a threat to world wheat production. Annual Review of Phytopathology, 49:465-481.

Singh DP, Singh HB, Prabha R (2017). Plant-microbe Interactions in Agro-ecological Perspectives: Volume 2: Microbial Interactions and Agro-ecological Impacts. Springer.

Sorkheh K, Masaeli M, Chaleshtori M H, Adugna A, Ercisli S (2016).

AFLP-based analysis of genetic diversity, population structure, and relationships with agronomic traits in rice germplasm from north region of IRAN and world core germplasm set. Biochemical Genetics 54(2):177-193.

Soundararajan RP, Kadirvel P, Gunathilagaraj K, Maheswaran M (2004). Mapping of quantitative trait loci associated with resistance to brown planthopper in rice by means of a doubled haploid population. Crop Science 44(6):2214-2220.

Stout MJ (2014). Host-plant resistance in pest management. In Integrated Pest Management pp. 1-21.

Tabu D, Selvaraj T, Singh SK, Mulugeta N (2012). Management of Adzuki bean beetle (*Callosobruchus chinensis* L.) using some botanicals, inert materials and edible oils in stored chickpea. Journal Agricultural Technology 8(3):881-902.

Tadesse A (2005). Some on-farm maize storage containers used in Ethiopia. In The 13th Annual Conference of Crop Protection Society of Ethiopia pp. 11-12.

Tanto T, Demissie A (2000). A comparative genetic diversity study for four major crops managed under Ethiopian condition. American Journal of Botany 87:783-792.

Tebkew D, Mohamed D (2006). Chickpea, lentil and grass pea insect pest research in Ethiopia: A review. pp. 260-273. In: Kemal Ali, Gemechu Keneni, Seid Ahmed, R. Malhotra, S. Beniwal, K. Makkouk and M.H. Halila (eds.). Food and forage legumes of Ethiopia: Progress and prospects. Proceedings of a Workshop on Food and Forage Legumes. 22-26 Sept 2003, Addis Ababa, Ethiopia. ICARDA, Aleppo, Syria.

Tefera T, Mugo S, Beyene Y, Karaya H, Gokunga J, Demissie G (2013). Post harvest insect pest and foliar disease Euphytica 123 resistance and agronomic performance of new maize hybrids in East Africa. International Journal of Plant Breeding Genetics, 10:1-13.

Wang X, Zhang Y, Xu X, Li H, Wu X, Zhang S, Li X (2014). Evaluation of maize inbred lines currently used in Chinese breeding programs for resistance to six foliar diseases. The Crop Journal, 2(4):213-222.

Worede M, Tesemma T, Feyissa R (2000). Keeping diversity alive: an Ethiopian perspective. Genes in the field: on-farm conservation of crop diversity. Lewis Publishers, IDRC and IPGRI, Boca Raton pp. 143-161.

Worku M, Twumasi Afriyie S, Wolde L, Tadesse B, Demisie G, Bogale G, Prasanna BM (2012). Meeting the challenges of global climate change and food security through innovative maize research. Proceedings of the National Maize Workshop of Ethiopia, 3; Addis Ababa, Ethiopia; 18-20 April, 2011. CIMMYT.

Yazici N, Bilir N (2017). Aspectual Fertility Variation and Its Effect on Gene Diversity of Seeds in Natural Stands of Taurus Cedar (Cedrus libani A. Rich.). International Journal of Genomics 2960624:1-5.