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Botanicals to Cope Stored Grain Insect Pests: A Review

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A B S T R A C T

The present article has been reviewed to know the importance of different plant products (botanicals) against storage insect pests of seeds and grains. Storage of grains is very important in agriculture for next generation and for food security. Among various biotic and abiotic factors which determine fate of grains during storage, insect pests are of economic importance as they cause significant loss. By reducing or eliminating the insect pest population while storage the rising demands of the increasing population of the world can be fulfilled. Among various storage insect pests *Sitotroga cerealella*, *Sitophilus* sp., *Rhyzopertha Dominica*, *Trogoderma granarium*, *Tribolium* sp., *Callosobruchus* sp. etc. are most detrimental. Insect damages include consumption of seed, debris of exuviae, webbing, and cadavers thereby makes the grain unfit for human consumption and also reduce quality as well as quantity. They manipulates storage environment resulted in development of hotspots which are congenial for the proliferation of storage fungi and other harmful micro flora. Conventionally we are exploiting synthetic pesticides to manage different insect pests which are hazardous to environment and ecosystem in various ways such as elimination of natural enemies; insect resistance and resurgence problem; making soil, water and air sick; have residual effects thereby cause different disorders or diseases to animals and humans. Biodegradable, non-residual, equally effective and easily available botanicals such as neem (*Azadirachta indica*), bach (*Acorus calamus*), phoolakri (*Lantana camara*), draik (*Melia azadarach*), kali mirch (*Piper nigrum*), Basuti (*Adhatoda zeylanica*) etc. may prove to be a better option to control insect pests including storage pests without affecting the quality of grains or seeds and without harming our ecosystem or environment. Thus botanicals may be recommended alone or as a part of IPM to control insect pests.

Keywords

Botanicals, Ecosystem, Environment, Grains or seeds, Storage insect pests, Synthetic pesticides.

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Introduction

Storage of the grains and seeds is very important in agriculture to start a new life and also in food security point of view. The quality grains and seeds during storage depends on various factors such as crop or variety, initial seed quality, storage conditions, seed moisture content, insect pests, bacteria and fungi (Amruta *et al.*, 2015). Among these factor insect does a significant contribution to the total loss. Total productivity of agricultural crops of India is 3 tonnes/ha as compared to global average *i.e.* 4 tonnes/ha (Anonymous, 2015a); out of which loss due to insect pests is about 26% as shown in figure 1 (Anonymous, 2015b) and food grain accounts for 20-25% damage by storage insect pests (Rajashekar *et al.,* 2010) which is really a brainstorming matter. Among various storage insect pests Angoumois grain moth (*Sitotroga cerealella*), maize/ rice weevil (*Sitophilus oryzae*), lesser grain borer (*Rhyzopertha dominica*), khapra beetle (*Trogoderma granarium*), rust-red flour beetle (*Tribolium castaneum*), legume weevil (*Callosobruchus* sp.) etc. are most detrimental (GC, 2006). With the increase in population the demand for the grains or other agricultural based products is also rising and by managing the loss due to storage insect pests we can fulfil the demand to some extent. Damage of grains due to poor ware housing facilities and damage by stored grain insect pests during storage, shipping and transportation, is very serious problem in South-East Asia and all over the globe (Upadhyay and Ahmad, 2011) especially in the developing countries (Talukder *et al.,* 2004; Dubey *et al.,* 2008). The insect pests not only damage the grain but also depreciate the weight and quality of stored grains (Rayhan, 2014). Insect damages include direct consumption of kernels, detritus of exuviae, webbing, and cadavers thereby makes the grain unfit for human consumption and also reduce quality and quantity. Insect infestation manipulate the storage environment resulted in development of hotspots which are congenial for the proliferation of storage fungi and other harmful micro flora (Rajashekar *et al.,* 2012).

Today, pest control technology is mostly dependent on synthetic insecticides (Azad *et al.,* 2013). The chemical pesticides dominated in pest management programmes throughout the globe since the discovery of DDT in 1939 (Misra, 2014). In India use of synthetic pesticides started after the green revolution came into existence. Among various pesticides used in India insecticides alone have 65% share (Anonymous, 2015c) as shown in figure 2. Pesticides and related issues remained a burning topic in media, debates, researches etc. since few decades. The different problems regarding residual effects, pest resurgence, prevalent environmental and ecological hazards, insect pest resistance and economy of farmers associated with currently used synthetic pesticides have directed us to botanicals (Zettler and Cuperus 1990; Elhag, 2000) which are environmental friendly, biodegradable, economic and are equally effective. Moreover, if grains are to be stored for food purpose pesticides sometimes prove to be poisonous or lethal. Plant products, such as aqueous or organic solvent extracts are being used in many countries as protectants of stored products (Fernando and Karunaratne, 2012).

Humans have used various plant metabolites for thousands of years in various ways such as dyes (e.g. indigo, shikonin), flavours (e.g. vanillin, capsaicin), fragrances (e.g. essential oils of rose, lavender), stimulants (e.g. caffeine, nicotine), hallucinogens (e.g. morphine, tetrahydrocannabinol), poisons (e.g. strychnine, coniine) and medicines (e.g. quinine, atropine) (Joseph *et al.,* 2012). Biological products of the plants may affect activities of the different arthropods including storage pests. Plants having some insecticidal properties have been exploited since long past to protect stored products from insect pests (Belmain and Stevenson, 2001). Some of the metabolites of plants are toxic such as pyrethrum, nicotine, rotenone etc. and some are repellents, antifeedants like azadirachtin, rape seed extract and others, like *Acorus calamus* act as sterilants (Ignatowicz and Wesolowska, 2015). Asian countries have abundant of these plant products which are traditionally used by the rural residents for preparations against insect control (Talukder and Howse, 1993). Therefore these plant products may be utilized either alone or as a part of integrated pest management. Moreover, since the pesticides came into existence the botanicals have been ignored; research and development focused on synthetic pesticides. Therefore research needs to be done to explore and exploitation of botanicals for pest management. Considering above problems and facts the present article has been reviewed under the following subheads.

Effect of synthetic pesticides on environment and ecology

Although pesticides are considered as a quick, easy, and inexpensive solution for controlling insect pests but they have polluted almost all the places and their residues found in soil and air and water all over the globe. Pesticides released into the environment may have long-term or short-lived effects in the normal functioning of an ecosystem (Zacharia, 2011). Regular and indiscriminate use of pesticides not only affected the environment and agriculture but also has entered in our food chain thereby affecting health and development of animals and human race (Rajendran, 2003). Synthetic pesticides along with the insect pest of economic importance also kill beneficial natural enemies and other organisms; thereby enhance pest problems as they are important in pest control. Among various pesticides, insecticides are generally the most acutely toxic class (Aktar *et al.,* 2009). Residual effect of insecticides was reported on natural enemies in which the suppressive effect was pronounced on the parasitic wasps that attack the obscure scale *(Melanaspis obscura),* a common scale insect pest of oak (Raupp *et al.,* 2001). Different arsenic derivates present in paddy soil were detected which appear to check the growth of rice (Li, 1983).

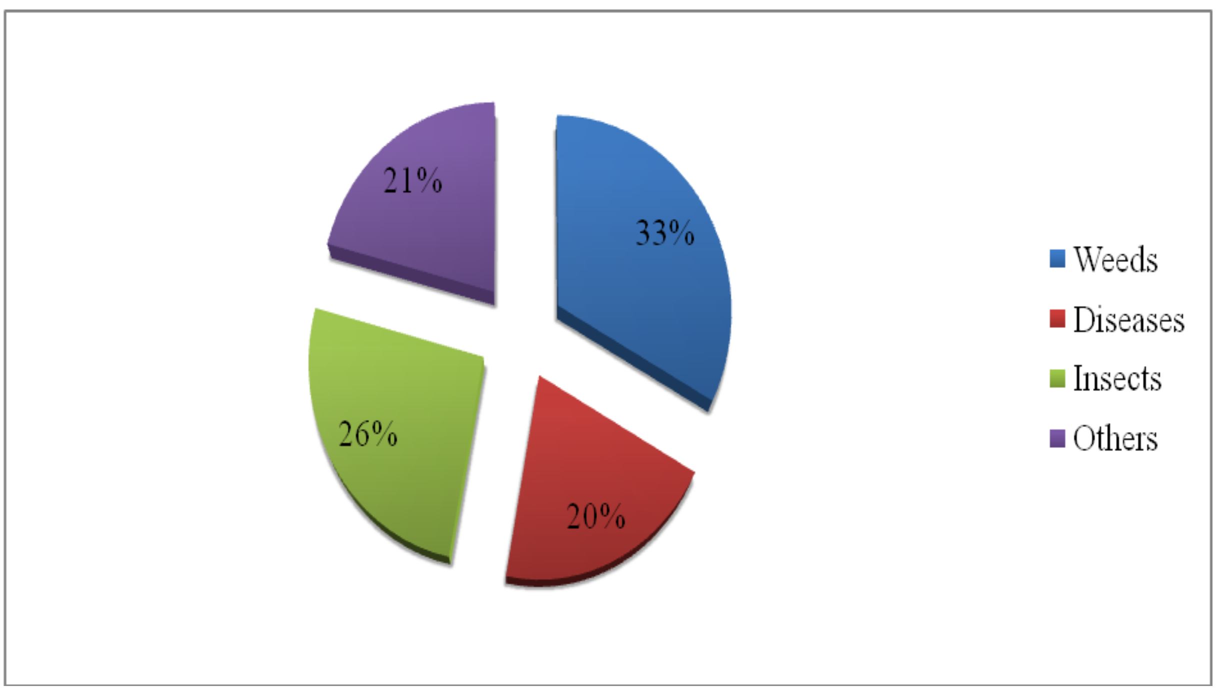
Persistence of pesticide in water, soil, air and food material poses a serious threat to living beings including humans. Pesticides leached out from crop land to various water bodies through water drainage by rain or irrigation (Larson *et al.,* 2010) thereby constituting a problem for the supply of drinking water to the population (Aktar *et al.,* 2009). Some of the volatile pesticides are serious risk to atmospheric pollution (Trajkovska *et al.,* 2009) which may cause various respiratory or allergic problems. The effects of the different pesticides are directly reflected from soil properties and soil micro-flora through which these pesticides undergoes degradation, transport and other various process (Hussain *et al.,* 2009). Organic soil without the use of chemicals (pesticides) results in improved soil health and quality (Johnson, 1986), and increased organic matter in the soil improves water holding capacity (Zacharia, 2011).

These pesticides when consumed directly or indirectly may cause serious disorders in living beings. Depending upon toxicity and exposure (length and magnitude) the pesticides have more hazardous effects on the human beings (Lorenz, 2009). Latest example is neoplasmic growth and respiratory problems observed in humans in Kerala due to the excessive and indiscriminate use of endosulphan which was banned later. The residues present in various leafy vegetables causes disorders like neural tube defect (NTD) among newborn children; in human (breast) milk and cow milk resulted in diseases like cancer, epilepsy, skin diseases and unbearable suffering (Rajendran, 2003). On the other hand natural pesticides have no such side effects and are biodegradable (Upadhyay and Ahmad, 2011). In the field also, the reduced use of pesticides and sustainable agriculture management practices protects our national pollinator resources (Mader and Adamson, 2012), which are very important for cross pollinated plants. Botanical are detrimental only to target pests, are effective in very small quantities, degrade rapidly and provide pesticide free food and a safe environment for living beings (Joseph *et al.*, 2012). Therefore botanicals should be included in the pest management practices and pesticides should not be applied to the limit that is hazardous to environment and ecology.

Insect resistance and resurgence

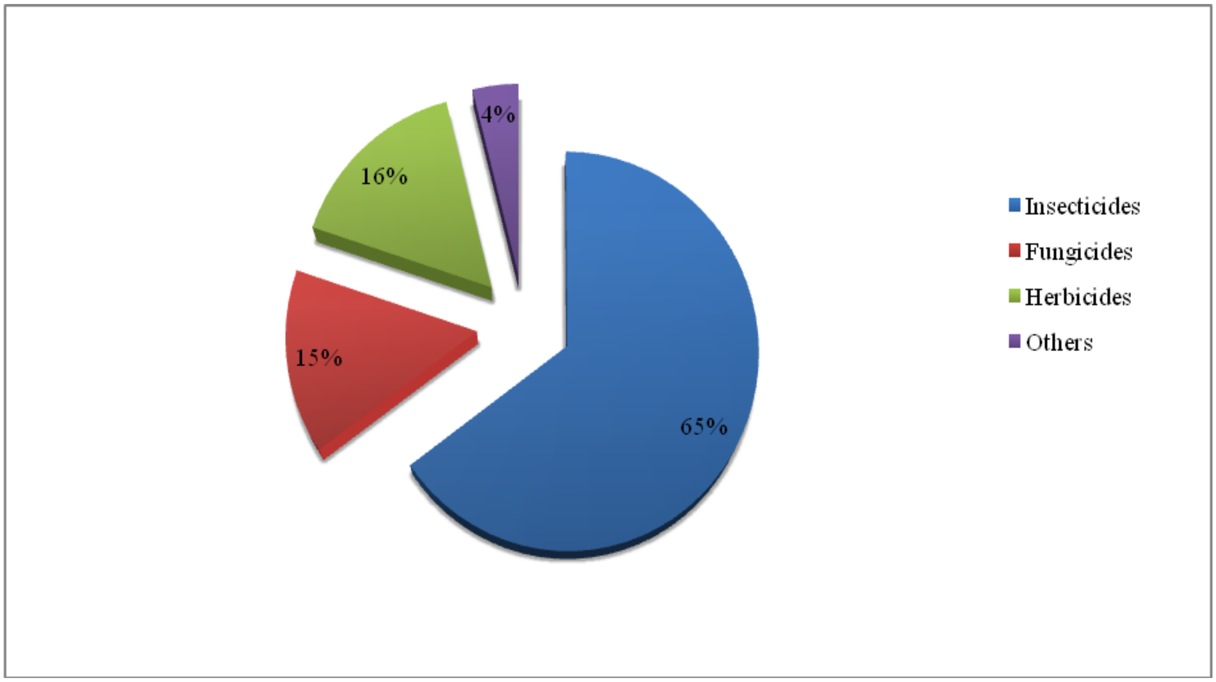
Resistance in insects is their ability to bear up doses of toxic substances that would be fatal to normal individuals or insects (Obeng, 2010) and resurgence is reappearance and increase of pests to a destructive level. Non-systematic and regular application of pesticides (insecticides) resulted reduction in their efficiency to control storage insect pests (Subramanyam and Hagstrum, 1996) due to genetic alterations in them. Many insect pests are very susceptible to pesticides initially, but due to alteration in their genetic constitution or through natural selection they become resistant and are able to reproduce (Zacharia, 2011). Also, regular use of pesticides especially broad spectrum kills the natural enemies and thereby increases the insect pests. Where insect pests have some controls from a beneficial predator or parasite, application of insecticides can eliminate both pests and beneficial insects (Zacharia, 2011). Insecticides sometimes eliminates primary pest provides opportunity to the secondary pests to become primary pests (Dhaliwal *et al.*, 2006) *i.e.* an increase in damage from such species were not originally very hazardous due to loss of their natural enemies. About one-third population of most damaging insects in the US was secondary pests earlier and became primary due to indiscriminate use of pesticides (Miller, 2004).

Fig.1 Crop yield losses due to insects and other pests in India



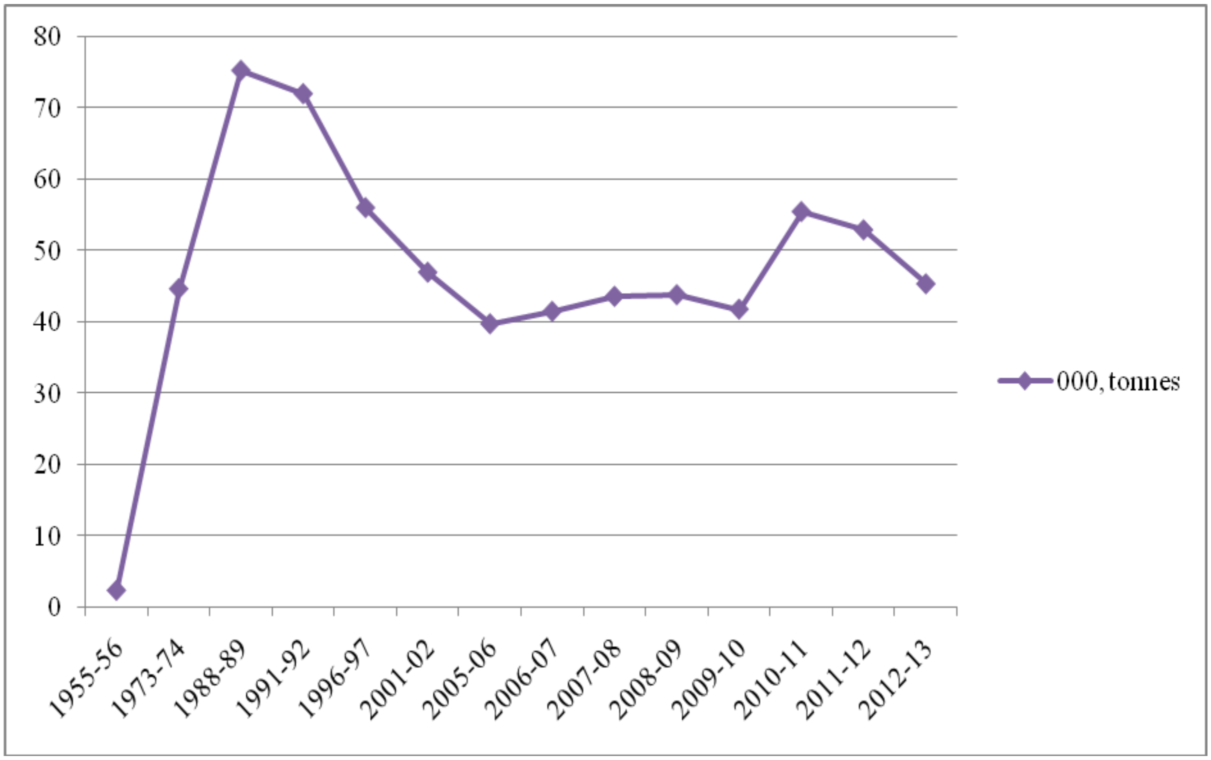
(Source: Directorate of Weed Research, Jabalpur (MP))

Fig.2 Pesticide use pattern in India



(Source: Krishi Jagran / By: KJ News / Updated: January 9, 2015 13:39 IST)

Fig.3 Pesticide use trends over the years in India



(Source: Krishi Jagran / By: KJ News / Updated: January 9, 2015 13:39 IST)

Table.1 List of some of the botanicals to manage different storage insects

S.No.	Plants (source)	Product	Target storage pests	References
1	*Clerodendrum inerme, Withania somnifera*	Ethanol extract	*Sitophilus oryzae*	Yankanchi and Gadache, 2010
2	*Withania somnifera*	Petroleum extract	*Callosobruchus chinensis*	Gupta and Srivastava, 2008
3	*Eucalyptus sp., Lantana camara, Azadirachta indica*	Ethanol extract	*Sitophilus zeamais*	Mulungu *et al.*, 2007
4	*Clerodendrum sp.*	Ethanol extract	*Sitophilus oryzae*	Roychoudhary, 1994
5	*Olax zeylanica*	Leaf powder	*Sitophilus oryzae*	Fernando and Karunaratne, 2012
6	*Acorus calamus*	Rhizome powder	*Rhizopertha dominica, Sitophilus oryzae*	Biradar, 2000; Channabasanagowda *et al.*, 2008; Sandeep *et al.*,2013
7	*Azadirachta indica*	NeemAzal	*Sitophilus zeamais*	Nukenine *et al.*,2011
8	*Azadirachta indica*	Azadirachtin	*Sitophilus oryzae*	Athanassiou *et al.*, 2005
9	*Azadirachta indica*	NeemAzal	*Prostephanus truncates*	Ogemah *et al.*, 2002.
10	*Chenopodium ambrosioides, Azadirachta indica*	Leaf powder	*Zabrotes subfasciatus*	Araya and Emana, 2009
11	*Piper nigrum*	Seed powder	*Sitophilus zeamais*	Issa *et al.*, 2011
12	*Lantana camara, Tephrosia vogelii*	Plant powder	*Sitophilus zeamais*	Ogendo *et al.*, 2004
13	*Lantana camara.*	Petroleum ether extract	*Callosobruchus chinensis*	Pandey *et al.*, 1986
14	*Azadirachta indica*	Plant powder extract	*Sitophilus oryzae*	Devi *et al.*, 2014
15	*Melia azadarach, Calotropis procera*	Leaves, bark and seeds powder	*Rhizopertha Dominica*	Khan and Marwat, 2004
16	*Azadirachta indica, Swietenia mahagoni*	Plants' seed oils	*Sitophilus oryzae*	Rayhan *et al.*, 2014
17	*Helianthus annuus, Gossypium spp., Olea europaea, Sesamum orientale, Glycine max, Brassica napus*	Plant oils	*Callosobruchus maculates*	Ibrahim, 2012
18	*Cassia senna, Caesalpinia gilliesii, Thespesia populnea var. acutiloba, Chrysanthemum frutescens, Euonymus japonicus, Bauhinia purpurea, Cassia fistula*	Methanol extract	*Trogoderma granarium*	Derbalah, 2012
19	*Adhatoda zeylanica*	Leaf extract and methanol extract	*Callosobruchus Chinensis, C.maculatus*	Misra, 2014
20	*Annona reticulata*	Root, stem, leaves and seeds extract	*Tribolium Castaneum*	Misra, 2014
21	*Clerodendron inermi*	Petroleum ether leafextract	*Callosobruchus Chinensis*	Misra, 2014
22	*Ageratum conyzoides*	Leaf, flower and root extracts	*Tribolium castaneum*	Misra, 2014
23	*Acorus calamus*	Rhizome powder	*Sitophilus zeamais, Sitophilus oryzae*	GC, 2006
24	*Artemisia roxburghii, A. annua, Mentha longifolia, M. Spicata Tagetus erecta, Melia azedarach*	Aqueous extracts	*Callosobruchus chinensis*	Rana *et al.*, 2014

Now, due to these problems, widespread environmental hazards and increasing costs the application of pesticides for the control of storage insect pests has been reduced (Bekele *et al.,* 1995; Bekele, 2002) all over the world along with India as shown in figure 3. Botanicals can be better option for management of insect pests as these degrade rapidly and do not give the chance to gain genetic resistance in the insect pests. If it is necessary to apply pesticides, should be applied in rotation *i.e.* use same pesticide every time should be avoided; or inclusion of botanicals may be done with the limited doses of insecticides.

Importance of botanicals in integrated pest management (IPM)

Pest management including postharvest infestation through integrated pest management (IPM) is now become an effective and most accepted approach (Rajashekar *et al.,* 2010). IPM approach is very effective way to prevent the development of resistance which emphasizes the judicial use of non-chemical methods (botanicals, light traps, natural enemies) and selective synthetic applications (Obeng, 2010). Integrated pest management signifies judicial and effective use available resources (Natural or synthetic) for the pest management without harming the ecological balance. Extensive use of synthetic pesticide should not be permitted or may be used with botanicals as a part of IPM to control the insect pests. Amruta *et al.,* (2015) recorded effective storage insect control and higher seed quality when treated with botanicals and emamectin benzoate. Insecticidal plant extracts have broad spectrum action and easy to prepare in farm levels (Azad *et al.,* 2013) from the locally available material. Other researchers, Nukenine *et al.,* (2011) reported that neem based viz. Neem Azal and NSO (neem seed oil) had sufficient efficacy against *S. Zeamais* to be a component of an integrated management. Another neem product Azadirachtin causes 100% mortality to *Sitophilus oryzae* (Athanassiou *et al.,* (2005). Some of the important botanicals to control or supress various storage insect pests like *Sitophilus oryzae, S. Zeamais, Callosobruchus chinensis, C. maculates, Tribolium castaneum, Rhizopertha dominica, Trogoderma granarium* etc. has been listed in table 1. Botanicals converted to harmless metabolites rapidly and do not help to build up inherited confrontation in targeted pests and are less detrimental to other beneficial organisms. Thus different botanicals can be used effectively to treat grains (Obeng, 2010) depending upon the locations as activity of botanicals varies across geographical locations (Kaushik *et al.,* 2007; Abdalla *et al.,* 2010); even with differences in storage durations and conditions. From the findings of different researchers we can say that botanicals may be effectively used in the integrated pest management (IPM) programme.

Effect of biopesticides (botanicals) on seed quality

Seed quality is determined by various biotic and abiotic factors such as genotype, moisture content of seed, storage conditions and pests like fungi, bacteria, insects etc (Amruta *et al.,* 2015). While we are storing the seeds for sowing purpose in the coming season or year, the viability and health is most important. Maintenance of seed quality during storage is essential for successful crop production and for maintaining integrity of the seeds that are prone to unpredictable threat of genetic erosion (Barua *et al.,* 2009). The infestation of seeds due to storage insect pests leads to loss of viability and vigour thereby affecting germination adversely (Rana *et al.,* 2014). Findings of different researchers showed that botanicals did not have unfavourable effect on germination value of the seeds (Gupta *et al.*, 1988; Pandey *et al.*, 1986; Khaire *et al.*, 1992). The killing or repellent property of various botanicals makes seeds unsuitable for insect pests during storage (Prakash and Jagadishwari, 1992) and enhance the quality parameters (germination, viability, vigour); but according to Kasa and Tadese (1995) use of botanical to manage *S. zeamais* in sorghum did not have any effect on seed germination. Botanicals might have the phytotonic effect thereby increase seed quality parameters Sandeep *et al.*, (2013); recorded higher germination, vigour index and less infestation during storage when maize seeds treated with sweet flag rhizome powder. Channabasanagowda *et al.*, (2008), Keshavulu and Krishnasamy (2005), and Khatun *et al.*, (2011) recorded similar results with botanicals in different crops. Therefore farmers may use botanicals for the management of stored grain pests without any adverse effect on germination (Mamun and Shahjahan, 2011; Ogendo *et al.*, 2004), viability and vigour of the treated seeds.

After reviewing findings of different researchers it can be concluded that storage insect pest such as *Sitophilus sp.*, *Callosobruchus sp., Tribolium castaneum*, *Rhizopertha Dominica*, *Trogoderma granarium* etc. does great loss and which needs to be control to feed the bursting population on this earth. Conventionally we are exploiting synthetic pesticides to manage different insect pests which are hazardous to environment and ecology in various ways such as eliminating natural enemies; insect resistance and resurgence problem; making soil, water and air sick; have residual effects which cause different disorders or diseases to animals and humans. Therefore biodegradable, non-residual, equally effective and easily available botanicals may prove to be a better option to control insect pests including storage pests without affecting the quality of grains or seeds. Thus botanicals may be recommended alone or as a part of IPM to control insect pests.

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