ISSN 2449-8955

European Journal of Biological Research

Review Article

Pesticides and food safety in Africa

Annabella A. Adewunmi, Stephen O. Fapohunda*

Department of Microbiology, Babcock University, Ilishanremo, Ogun State, Nigeria
*Corresponding author: Stephen O. Fapohunda; E-mail: oystak@yahoo.co.uk

Received: 01 February 2018; **Revised submission:** 13 April 2018; **Accepted:** 30 April 2018

DOI: http://dx.doi.org/10.5281/zenodo.1237542

ABSTRACT

African countries have experienced nonconformance in the levels of pesticides for local consumption and export. Sometimes this leads to rejects and other forms of embarrassment from the importing countries. Economic challenge and lack of awareness heighten the overall cost of interventions in pesticide-related food safety management. For example, not a few of the infractions were a result of incorrect ways of pesticide application. The hazard accompanying chemical pesticide application has left open a window of biological alternatives which this review article seems to explore**.** The bio-alternatives, including green pesticides cancel out the adverse effect of residual chemicals on crops in farm and store and so make it more attractive.

Keywords: Pesticides; Food security; Human health; Green-pesticide; Africa.

1. INTRODUCTION

With an annual growth rate of 1.2%, the world population is estimated to reach 9 billion by 2050 [1, 2]. United Nations (UN) estimates, indicate that 95% of this increase in world population will occur in the developing countries and regions such as sub-Saharan Africa [3, 4], hence the need to step-up food production through increase in agricultural productivity. In Africa, crop losses caused by pests and diseases are two major barriers to increase in agricultural produce. This has led to the overzealous application of agrochemicals or pesticides to farm crops [2, 5], and this in turn has brought its own set of problems both to the farmers and the environment [6-10]. Pesticides are chemical substances used to kill, repel or control pests or used to prevent the damage the pests may cause. They are commonly used to control a variety of agricultural pests that are likely to damage farm crops and livestock, leading to a substantial reduction in farm productivity. Initially, with little insight into the long term effect, pesticides use seemed to be a success, until the incidence of resistance. Hitherto, easily controlled pests became uncontrollable due to adaptation leading to application of higher amounts to ensure effectiveness. The development of new chemicals resulted in undesirable side effects both to the farm produce and the environment [2].

2. CLASSIFICATION OF PESTICIDES

The level of toxicity by pesticides is classified by WHO [11] into 4 categories. These are; class I: very toxic, class II: toxic, class III: slightly toxic and class IV: unharmful. Some common categories of pesticides include insecticides, algicides, herbicides, biocides, fungicides, molluscicides, nematicides, and rodenticides. Pesticides are also grouped according to their chemical properties and these include the organophosphates, organochlorines (chlorinated hydrocarbons), carbamates and thiocarbamates, and pyrethroids (Table 1). Pesticides formulations and presentation are in solid, liquid and gaseous forms.

Just before the commencement of the current millennium, new techniques were introduced which are mainly biological (chemical free) and include microbial pesticides, biochemical pesticides and genetically modified organisms (GMOs) to salvage the situation of massive spread of agro-chemicals in agricultural fields. However, in the tropical regions of sub-Saharan Africa, the use of pesticides (agro-chemicals) is still the common practice. Chemical compounds such as DDT, HCH and Lindane that are environmentally recalcitrant are today banned from use in farms in developed countries of the world but tragically remains in popular use in developing countries [2]. The persistent pesticide residues therefore readily contaminate food and disperse in the environment. This is particularly prevalent in regions of lack of progress and economic challenge. Food quality becomes compromised and the environment adversely affected. Agbohessi [12] stated that the growing use of pesticide in agriculture contributes significantly to environmental pollution. Velisek [13] had viewed the role of pesticides to environmental pollution to be on par with emissions from industrial sources. Only about 0.1% of the farm sprayed pesticides reach the target pests, the excess is dispersed in the ecosystems where it contaminates the land, water, and air [14] thus endangering lives. Even at non-lethal doses, these chemicals disrupt the nervous system, liver, hormonal regulation, reproduction, embryonic development and growth in fish [15-20]. In South Africa, agricultural residue pesticides such as DDT, malathion, cypermethrin, aldrin, and endrin have been in the waters of Western Cape. They express bio-concentration and bio-magnification along the food value chain with possible dire health consequences to man and livestock [21].

In West Africa sub region, farmers use large quantities of pesticides, sometimes not appropriate in doses and efficacy [12]. The use of banned pesticides is not uncommon, for example, Endosulfanis still in use though it was banned in 2007 due to its ability to pollute the environment and poison human beings [22]. Endosulfan (6,7,8,9,10, 10-hexachloro 1,5,5a,6,9,9a-hexahydro-6,9-methano-2,3,4-benzodioxathiepine-3-oxide, CAS No.115-29-7) is an organochlorine pesticide rated as the most hazardous to the environment due to its non-biodegradable nature and possibility of bio-magnification as it migrates along the food chain [23]. Tihan, a milder and more environmental biodegradable pesticide has been developed to replace Endosulfan, however, the two are still in use simultaneously in West Africa [12] thereby putting not only the environment but also our food crop at perpetual risk.

Sodium chlorate and sulphuric acid were in use in the 1940s and in the late 1940s synthetic pesticides such as DDT, BHC, Aldrin, Dieldrin, Endrin, Chlordane, Parathion, Captan, and 2,4-D were developed and widely used. These new products were cheap, effective and generally accepted. However, in 1962, the problems and danger of the indiscriminate use of pesticides to the environment was highlighted. Even when many African countries are familiar with, and possibly signatories to many global initiatives like FAO code of conduct on distribution and use of pesticides, Codex, Cartagena Protocol, Montreal Protocol, Stockholm convention, needless application leading to environmental pollution and the concerns about health of living organisms still subsists. Reasons for these include inadequate expertise [24]; conscious use of obsolete pesticides [25] and different monitoring capacities that vary from one location to another [26].

In 1970s-1980s, many new products were born out of research including the popular and greatest selling herbicide 'glyphosate', third generation insecticides and new spray treatments. From the 20th to the 21st century, an entirely new family of pesticides or agrochemicals has been birthed. Modern research and advances in chemistry has made these products safer, more selective and much more environmental friendly, with effective usage rate only requiring grams rather than kilograms per hectare [27]. These modern agrochemicals have helped farmers boost productivity significantly, particularly in regions like Sub-Saharan Africa (SSA) where crop yields have been low. In a Kenya survey, the commonly used insecticides on vegetables included dimethoate (WHO II), used by 48% of farmers, lambda cyhalothrin (WHO II, 27%), cymoxanil (WHO II, 22%), cypermethrin (WHO II, 22%), cyfluthrin (WHO Ib, 20%), mancozeb (WHO U, 18%), and deltamethrin (WHO II, 14%). Lack of Personal Protective Equipment (PPE), reduced literacy level and geographical location contribute to pesticide-related cost of illness (COI). When morbidities arise from such exposure, cultural therapists deploy milk, lemon juices, honey, and herbs [28].

3. TYPES OF PESTICIDES

There are various types of chemical pesticides. Their characteristics and mechanism of action are as shown in Table 1.

4. PESTICIDES AND FOOD SAFETY IN AFRICA

Agriculture remains the major occupation in most African countries and dominated by small and medium holder farmers with minimal education. Pesticide use in Africa has therefore been reported as low compared to other continents. Agrow [30] reported a range of approximately 2-4% of global pesticide market of US$ 31. Similarly, Repetto and Baliga [31] reported average pesticide use in Africa per hectare as 1.23 kg/ha, while 7.17 kg/ha has been recorded in Latin America and 3.12 kg/ha in Asia. One conclusion could be that most farmers in Africa being small holder farmers, and their output in terms of food production is low, do not usually consider the use of pesticides [32]. Pesticides are preferably used on large scale, commercial farming of cash crops such as cotton, cocoa, oil palm, coffee and vegetables. The fact remains that whether pesticide use in Africa is low or not, the risk and impact arising from the toxicity of the chemicals where used, cannot be overemphasized. Previous studies have reported poor pesticide practices by African farmers [32-34] and these practices include use of unsuitable products, poor handling, wrong dosage, timing and targeting of application, non-calibrated equipment, and application equipment that is poorly maintained [35]. Others are the use of banned products, mixture of products, mixing with bare hands, splashing pesticides on crops using brushes or twigs, lack of minimal protective clothing and even tongue-testing to assess concentration strength has been reported [34, 36-38]. In 2018, South Sudan played host to a technical team from the UN due to the invasion of the farms in 8 states by army worm [39]. A cocktail of pesticides is being proposed which may go with the attendant consequences, if misapplied.

This misuse of pesticide results not only in the control of the intended pests but also has serious impact on the operator, the farm crops and livestock, the health of the consumer, soil organisms, and contamination of the entire environment [40, 41]. United Nations report [42] has highlighted the growing health and environmental hazards from chemicals and stated that the potential cost of pesticide-related illnesses in sub-Saharan Africa between 2005-2020 could reach $90 billion. United Nations Environmental protection (UNEP) estimated the cost of lost work, medical treatment and hospitalization due to pesticide poisonings among small scale farmers in 37 African countries to be $4.4 billion. In 2010, Uganda's National Environment Management Authority reported that each farmer loses 24.6 days per year due to pesticide poisoning, 9.4 days due to respiratory illnesses and 15.2 days due to skin infections [43].

In 2015, the EU banned some agricultural food items meant for export from Nigeria due to the presence of high levels of dichlorvos pesticide. The food items include beans, sesame seeds, melon seeds, dried fish and meat, peanut chips and palm oil [44]. The European Food Safety authority (EFSA) claimed that the rejected food items were found to contain between 0.03-4.6 mg/kg of dichlorvos pesticide while the acceptable Maximum Residue Limit (MRL) is 0.01 mg/kg. This pesticide is usually applied during storage while the products are being prepared for export. In 2013, EU issued fifty (50) notifications of border refusals to Nigerian beans exporters over high level of unauthorized pesticide. In 2015, EU issued thirteen (13) border rejections alert to the same beans exporters. Generally, between 2008 and 2013, there has been a significant number of border refusals of food imports by the EU due to non-compliance of exporting countries with its food safety standards, which amount to about 9233 rejections between 2008 and 2013 [45]. Fruits and vegetables are the most commonly affected product usually refused entry into EU markets as a result of the exporters failing to meet EU standards. The surveillance studies on vegetables in Ghana presented a mixed bag. While residues were found at concentrations not particularly considered a health problem with occasional exceedances in respect of chlorpyrifos, diazinon and permethrin [46], an earlier investigation by the Christian Aid [47] and

NPA [48] the use and misuse of pesticides indeed constituted a major threat to the lives of farmers because of exceedance of EU MRLs. Although raw agro produce are particularly primary targets, industrial products like soft drinks and fast foods are not spared [49, 50].

Table 1. Various types of pesticides (insecticides, fungicides and herbicides), examples, their characteristics and mechanism of action.

S/No	Type: Chemical	Examples	Characteristics	Mechanism of action
1.	Organophosphates	• Chlorpyrifos • Dimethoate • Fenthion • Naled • Temephos • Trichlorfon	- Made from phosphoric acid - Most are insecticides - They are highly toxic - It breaks down faster in the soil, food and feed	These control pest by acting on the nervous system, interfering with the nerve impulse transmission, disrupting the enzyme cholinesterase that regulates acetylcholine (a neurotransmitter)
2.	Organochlorines (chlorinated hydrocarbons)	• Aldrin • Chlordane • Dieldrin • Endolsulfan • Endrin	- Generally persistent in the soil, food and in human and animal bodies. - They can accumulate in fatty tissues - Traditionally used for insect control and mites. - They do not break down easily. - Some such as DDT and Chlordane are no longer in use because they stay in the environment for a long time	They control pests by disrupting nerve impulse transmission
3.	Carbamates and Thiocarbamates	1.Insecticides • Carbaryl (banned due to health risks) • Propoxur • Methomyl • Carbofuran • Thiodicarb 2. Herbicides • Barban • EPTC • Propham • Triallate 3. Fungicides • Nabam	- They are made from carbamide acid - They are less persistent in the environment - Mild health hazards to human and animals especially the herbicide and fungicide range. However, health risk is higher with insecticides	They control pest by acting on the nervous system, interfering with the nerve impulse transmission, disrupting the enzyme cholinesterase that regulates acetylcholine, with enzyme effect usually reversible
4.	Pyrethrin (synthetic version of Pyrethrin, modified to increase stability in the environment)	• Cyhalothrin • Cypermethrin • Deltamethrin • Esfenvalerate • Permethrin	- Stable in sunlight (do not degrade quickly)	Disrupts nerve impulse transmission (increases sodium flow into axon), which stimulates nerve cells and eventually causes paralysis

Source [29].

Acute or chronic exposure of humans to dichlorvos can have dire consequences. It inhibits an enzyme, acetylcholinesterase [51] with neurotoxic effects such as difficulty in breathing, diarrhea, abdominal cramps, vomiting, salivation, sweating, nausea, convulsions, dizziness, weakness, tightness in the chests, blurred vision, eye and skin irritation, eye pain, runny nose, wheezing, laryngospasm, cyanosis, and at high concentrations convulsion and coma. As at date, there is no conclusive information on the carcinogenic effects of dichlorvos on humans. Symptoms in animals include ataxia, salivation, dyspnea, tremors and diarrhea. Toxicological studies on animals showed an increase in the incidence of tumors of the pancreas, mammary glands and stomach.

According to Varo [51], dichlorvos has been found to be a highly toxic pesticide. In a study to determine the residual levels of the commonly used dichlorvos on small and large scale vegetables farms in Lusaka, Zambia, it was reported that the levels of dichlorvos was significantly above the MRL [52]. Similarly, in Northeastern Nigeria, research showed that farmers and traders use locally formulated pesticide which contains high levels of dichlorvos (about 7.7% w/v) in trade [53]. Therefore, consumers of such vegetables and other commodities with such levels of dichlorvos residues in Zambia and Nigeria, and in Africa as a whole are at risk to the health issues outlined above in the long run, since they export to other African countries.

5. PESTICIDE STANDARDS REGULATION

Just like drugs, pesticides are subject to regulation. The safety of pesticides is reviewed by the authorities before they are allowed to be used on crops. In Nigeria, the Standards Organization of Nigeria (SON) and NAFDAC are responsible for setting these standards, controls and enforcement. These standards are synchronized with the Codex Alimentarius (Codex Alimentarius Commission) which was established by FAO and WHO in 1963. The commission ensures coordination of all food standards work embarked upon by international governmental and non-governmental organizations.

The use of pesticides is usually authorized only after a risk assessment has been done and checked that any residue remaining after correct use of the pesticide will not lead to any consumer concern. The potential residues on a harvested crop are regulated by a maximum residue level (MRL) which is set As Low As Reasonably Achievable; the ALARA principle [54]. MRL usually include wide safety margins that are well below the level that could pose any adverse effect on consumers' health and safety. Maximum Residue Levels (MRLs) are part of Good Agricultural Practices (G.A.P). MRLs are primarily trading standards, which are applied to help ensure that residue levels do not pose unacceptable risks for consumers of such food. Pesticides regulation in the EU, is governed by Directives (EC) No 396/2005. This Directive which came into effect in 2008 establishes the MRLs of pesticides allowed in products of plants and animal origin intended for consumption, based on scientific evidence from risk assessments. This Directive replaced all pesticides standards among EU member states which existed prior to 2008. Figure 1 illustrates how residue levels are measured.

The ADI and ARfD are obtained through animals such as mice testing. These are set based on the highest dose where no recognizable harmful effects are observed; the No Observable Adverse Effect Level (NOAEL). The international practice is that the NOAEL is divided by an uncertainty factor of at least 100 to compensate for potential differences between animals and humans; and for differences between individuals [54]. Since the NOAEL may differ for chronic (long term) and acute (short term) effects, the ADI and ARfD may be set at different levels.

When MRLs are exceeded, it does not necessarily imply a risk to health but an indication that a pesticide has been incorrectly used. Food products which have residues exceeding MRL cannot be sold. When a farmer uses a pesticide according to the label instructions and Good Agricultural Practice (GAP), the residues in crop at harvest do not normally exceed the Maximum Residue Level established in the country of use. However, since MRLs are not harmonized world-wide, MRL exceedances can occur when products are exported to a country with a lower MRL for the specific pesticide and crop combination.

In South Africa, according to Mutengwe [26] the implicated pesticides that exceeded established MRLs were imazalil (37.71%), prochloraz (28.69%), and iprodione (5.74%). The unregistered pesticide residue most often found on grapes and avocados was also imazalil (62.23%) and, on nectarines diphenylamine (11.15%) and the exceedances of MRL values involved oranges (43.44%), avocados (27.87%), grapefruits (7.38%), and lemons (6.56%). This led to a change of mind and negative perception by the public and reconsideration by the government on how to control pesticide use globally. It is not in all cases that residues went as higher than the MRL set by regulating bodies as observed in the survey carried out in Sudan [55]; although high levels sometimes are controlled by biological means [56]. In Libya, organochlorines and other pesticides from the field, were detected in some fish at concentrations higher than the permissible limit, according to FAO where concentrations were calculated in mg/kg BW of fish [57].

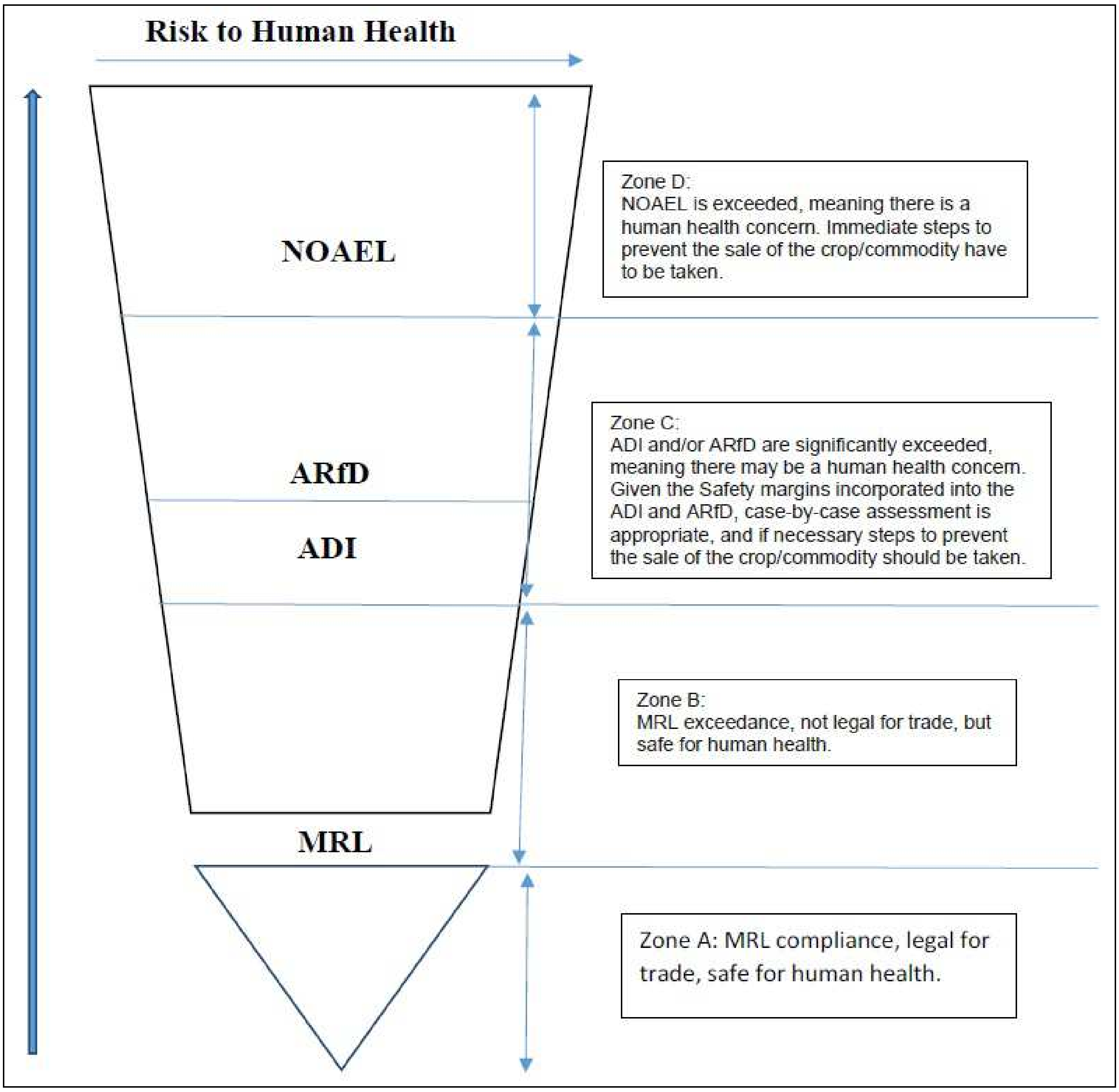

Figure 1. Measuring Residue levels [54].

Legend:

NOAEL (No Observable Adverse Effect Level): the highest exposure level at which no adverse effects can be identified in tests.

ARfD (Acute Reference Dose): a toxicological safety limit specifying the amount of a substance which can be ingested on a single day without any effects on the health of the consumer.

ADI (Acceptable Daily Intake): a toxicological safety limit specifying the amount of a substance which can be ingested every day over an entire lifetime without any recognizable risks to the health of the consumer.

MRL (Maximum Residue Level): a legally fixed maximum concentration for a particular active ingredient in a particular crop. A trade standard, intended primarily to check that a pesticide has been applied correctly.

6. HEALTH EFFECTS DUE TO CONSUMPTION OF FOOD WITH PESTICIDE RESIDUES

Pesticides are potentially toxic and hence are hazardous to humans and animals resulting in both acute and chronic health effects depending on the dosage and ways in which persons are exposed. Exposure can be through contact with the skin, ingestion or inhalation. When people consume food with large quantities of pesticides, above safe limits, it can lead to acute poisoning or long term health effects including cancers. Chronic toxicity occurs when subjected to small doses over a period of time. Imazalil is among the persistent pesticides on edible fruits such as grapes, with an allowed MRL of 5 mg/kg. When consumed over a long of time in concentrations above the MRL, it can cause mortality issues and significant brain enzyme depression [58]. The numerous suspected health effects that have been associated with chemical pesticides include dermatological, gastrointestinal, neurological, carcinogenic, respiratory, reproductive and endocrine effects [59-62]. In some cases can lead to hospitalization and death [59, 63]. Pesticide residues and food safety has also been an issue of concern from the consumers perspective, although the rating seemed to be far below food safety caused by bacterial pathogens. In 2011, a workshop organized by EU to capture opinions of stakeholders on food safety issues in fresh foods reported that consumers ranked bacterial pathogens as the first, followed by foodborne viruses, with Pesticides residues and mycotoxins taking the third and fourth positions respectively in the ranking [64]. This shows that though pesticide residues cause serious health effects on consumption of foods contaminated with them, other more serious causative agents such as bacterial pathogens and viruses are of more importance to the consumers and should as a matter of priority be the main focus. In the same workshop, these consumers proposed as control measures good agricultural practices, good hygiene practices and food safety management system certifications.

7. CURRENT TRENDS IN FOOD AND CROP PROTECTION

In the last decade, there has been new development in food and crop protection. They are the genetic engineering of organisms, the organic-chemical-free agriculture and green pesticides.

1. Genetically modified organisms (GMOs) such as engineered soybeans, maize, and tomatoes came as a solution to food security and revolutionized agriculture [65]. These crops were modified to be tolerant to glyphosate, a common herbicide. South Africa in recent times delved into the development of alternative methods of pest control in order to reduce environmental levels of organic and inorganic pesticides. One of these developments is genetically modified (GM) crops, such as GM maize and cotton. More than 90% of farmers plant GM maize and cotton and South Africa is currently ranked 9th worldwide in planting GM crops [66]. There are many advantages of using GM crops for pest control. First, the crop is protected continuously in the field and the time used to detect pest infestation is reduced. Secondly, there is protection of the plant part that is difficult to reach with insecticide spraying. Thirdly, control is no longer affected by the weather. The crop is protected even if the field conditions are not suitable for aerial or ground application of insecticides [67]. Also, there is general reduction in insecticide use. Although GM crops have become a major component of insect control strategies, a proper perspective of its potential demands a close look at limitations and uncertainties that may reduce its future impact on agriculture such as development of resistance of target pest and effect on potential non-target organism [21].

Secondly, sprays of the bacteria, *Bacillus thuringiensis*, have been used to control pests. The crystalline protein produced by these bacteria kills certain insect species and have limited effects on most non-target species [68]. The use of commercial *Bacillus thuringiensis* sprays have, however, been limited due to their relatively high cost, poor crop coverage, rapid environmental inactivation, and less desirable level of pest control, when compared with less expensive conventional chemical insecticides [69]. Toxin-encoding genes from *B. thuringiensis* have been expressed in transgenic crop plants, providing protection from some key pests [68].

In South Africa two of these key pests of maize are the lepidopteran stem borers, *Busseola fusca* and *Chilo partellus* which are of economic importance throughout Southern and Eastern Africa. Large-scale planting of *Bacillus thuringiensis* (Bt) crops to control these pests started in South Africa in 1998. Bt cotton for control of the boll worm complex, particularly the African bollworm, *Helicoverpa armigera* was also introduced into South Africa during the same period. Generally, there is reduction in insecticide use. For example, reduced insecticide use was reported from the Makathini Flats region of Kwa-Zulu Natal, South Africa, where 95% of smallholder (1-3 hectares) cotton producers grew rain-fed Bt cotton. Farmers that adopted Bt cotton reported reduced insecticide use and a reduction in labour [70]. However, in India there have been reports of Bt cotton failures and claims of mass suicide due to significant financial losses by the farmers [71]. The government of India claims the pink bollworm, a major pest that attacks cotton crop has already developed resistance to the new technology, as observed in 2015/16 crop year, where most cotton crops were significantly damaged by the bollworm and whitefly in most of the farms in India [72]. In 2002, after field trials with Bt cotton became successful, Indian government officially approved the commercial release of Bt cotton to farmers and by 2010, almost all the farmers in India had migrated from non-Bt cotton to Bt cotton because of the advantages of high income gained through better pest management at lower cost. Expenditure on chemical pesticides was drastically reduced. Bt cotton technology gave a boast to Indian cotton business and helped India come to be the second largest producer of cotton in the world. The recent development of pest resistance to Bt cotton technology has become a serious threat to Indian cotton business. Burkina Faso in Africa, has completely rejected the introduction of Bt Cotton technology to its farmers both for political and economic reasons. Herring and Rao [71] in their study of Bt cotton failure reported that each hybrid of cotton consist of different germ plasm and the mechanism for obtaining the Bt transgene which confer insect resistance trait on them is not exactly the same, leading to variations in results in yields comparisons.

2. Organic agriculture:

The development of organic agriculture which respects the normal functioning of the ecosystem, avoids the use of pesticides and leads to food free of synthetic chemicals and thus healthier. However organic agriculture is limited in scope and does not have potential for mass production needed to feed the world [73]. Organic agriculture thus improves food safety but cannot cope with food security.

3. Green pesticides:

These are nature-oriented and beneficial pest control materials used to control pest populations thus increasing food production. Green pesticides are botanical and natural materials that are used to reduce pest population and increase food production. They are safe and eco-friendly, and are compatible with environmental components than synthetic pesticides. They include substances such as plant extracts, hormones, pheromones, and toxins of organic origin. It also includes many other aspects of pest control such as microbial, entomophagus nematodes, plant derived pesticides, secondary metabolites of microorganisms and mineral-based controls used to express resistance to pests. More recently, under this umbrella of green pesticides, are extremely biodegradable synthetic and semi-synthetic products in pest management.

Green pesticides are attractive alternative to chemical pesticides because they reduce the negative impacts to human health and the environment, the reason it is now a contemporary issue [6]. However, their use in Nigeria and other parts of Africa is still hampered by some challenges. First, there is still no appropriate application technology particularly the use of oils and dust formulations [75]. Secondly, the residual effect of green insecticides is short-lived compared to synthetic chemicals, hence repeated applications are required to obtain reasonable crop protection. Thirdly, they are yet to be available to farmers in commercial quantities. Fourthly, there is the problem of farmers' acceptability of this new technology in pest control [76] which calls for training and promotion of the use of these green pesticides in integrated pest management by the relevant authorities. Awareness campaigns and farmer-friendly capacity building can resolve most of these issues.

Table 2. Types of green pesticides (botanicals, biological and mineral-based controls).

Types	Description	Target
1. Botanical pesticides	These are plant extracts used as insecticides to control insects. They are usually harvested by macerating plant tissues high in active ingredients and distilling the specific compound. The advantage of using botanical pesticides is their rapid degradation in the environment.	
i. Neem	Insecticidal extract (namely azadirachtin) from seed and bark of the Neem tree (widely found in India), which act as insect repellant, anti-feedant and interferes with growth. Neem can also be used as systemic insecticide when applied directly to the soil and taken up by the plant and transported to the shoots and leaves. Multiple applications are required as it degrades easily (with 3-7 days).	Effective against caterpillars, flies, whitefly, scales, and aphids.
ii. Pyrethrium	Easily broken down by stomach acid of mammals, hence toxicity is very low except if application doze is increased above recommended on label.	Effective against soft bodied garden pest such as scales, whitefly, mealybugs and thrips but ineffective against mites.
iii. Horticultural oils	They work by disrupting insect feeding and egg laying. Egg covered with oil suffocates the developing pest. Have minimal phytotoxic effects on plants when used properly.	All insects
iv. Dormant & summer oils	They can be applied to plants during growing season.	Effective against eggs, nymph, larva, and adult leaf rollers, aphids, mites, and scales.
v. Traditionally used botanical insecticides e.g. Nicotine, Rotenone, Ryania, Sabadilla, and pyrethrum	Nicotine and tobacco have long history of use and is very effective against insects but also has high toxicity against mammals. Hence being considered for regulatory phase out. Rotenone made from isoflavonoid, an extracts of the tropical legumes *Derris* and *Lonchocarpus*. It is highly toxic to insects and fish but also moderately toxic to mammals. Rotenone has been widely used on ornamental crops, but has been phased out in the US and Canada during regular re-evaluation. However, its use is being continued in other countries. Sabadilla is an extract from the seed of *Schoenocaulon officinale*, a neo-tropical lilywhich contains veratridine alkaloids with a neurotoxic mode of action. It high toxicity as contact insecticide and low mammalian toxicity. Ryania is an extract from *Ryania* sp., a South American shrub. It contains the active ingredient di-terpene alkaloid ryanodine, which is a contact and ingested insecticide against horticultural and ornamental crop pests. Pyrethrum is an extract of *Chrysanthenum cinerariaefolium* plant. It is toxic to both mammals e.g. cats, fish and also insects	Effective against agricultural insects such as lepidoptera, leafhoppers, and thrips. Also mosquitoes, fleas, flies, moths ants bees,

Types	Description	Target
2. Natural (biological) products	These are living organisms used to control pests and are called biological controls or biological agents. When a microorganism is packaged and sold to control a pest, it is legally considered a bio pesticide and is regulated as such [74]. However, Nematodes are not regulated pesticides though equally used as bio pesticides.	
i. *Bacillus thuringiensis (Bt)*	*Bt* is a naturally-occurring bacterium. Commercial Bt products are formulations of the bacterial toxin and are non-living. Bt can be sensitive to ultraviolet light (sunlight) and is most effective when applied in overcast conditions or late in the day. Most Bt products degrade within 24 hours regardless of sunlight conditions or temperature, giving them a very short period of effectiveness once they have been applied. Multiple applications are thus needed for sufficient management of pests.	Feeds on the larval stages of insect pests such as mosquitoes, Colorado potato beetles, and cabbage loopers. *Bt.* var. *kurstaki*feeds on caterpillars, commonly found on vegetables and fruits.
ii. *Beauveria bassiana*	*Beauveria bassiana* is a soil borne fungus. *It is* applied to the target pest as a spore. Once the spores have contact with the insect exoskeleton, they grow hyphae that secrete enzymes, which in turn dissolve the cuticle. These fungal hyphae then grow into the insect, feed on its body tissue, produce toxins, and reproduce. It takes up to seven days for the insect to die. If moist conditions (92 percent humidity or greater) are present during this time, *B. bassiana* will “bloom” and release more spores into the environment to repeat the cycle on other pest insects.	Effective against thrips, aphids, whitefly, caterpillars, beetles, and subterranean insects like ants and termites
iii. Nematodes	Nematodes are multi cellular organisms commonly referred to as microscopic worms.	Effective against soil-dwelling insect pests such as root weevils and cutworms, and can also control pests that pupate or hibernate in the soil such as codling moth larvae
iv. *Nosema*	*Nosema* are protozoans.	*Nosema locustae* is used to manage grasshoppers
v. Fermented microbes e.g. abermectin	Abermectin, is a fermented product of *Streptomyces avermitilis*	Used in baits for household insect pests. The fermented product is very toxic to caterpillar pests such as cabbageworm, cabbage looper, diamondback moth, armyworm, and cutworm, as well as fruit flies such as spotted wing drosophila.
3. Mineral Controls	Insecticides developed from mineral resources mined from the earth. The toxicity of mineral-based insecticides depends on the chemical properties of the mined elements. Some, such as sulfur are registered for organic use and have relatively low toxic effects on people and non-target organisms. In	

Types	Description	Target
	contrast, lead arsenate is a natural mineral product that was cancelled as a pesticide in 1988 due to its toxicity and persistence in the environment.	
i. Diatomaceous earth	Fine particle dust comprised of fossilized diatoms.	Effective against slugs and soil-dwelling insects
ii. Elemental Sulphur	Elemental sulfur is a finely ground powder that can be applied either as a dust or a spray. This mineral is one of the oldest pesticides known, and reported pest resistance is rare. Sulfur acts as a metabolic disruptor on insects.	Effective against aphids, thrips, and spider mites
iii. Iron phosphate	They come in pellets and liquid formulations.	Effective against slugs and snails when combined with baits.
iv. Kaolin	Kaolin is fine clay that is sprayed on plant foliage or fruit to deter feeding and egg laying of insects.	Effective against apple maggot, codling moth, and leafhoppers.
v. Soap	Natural soaps are derived from plants or animal fat.	Effective against aphids, scales, whitefly, mealy bugs, thrips, and spider mites.

Source: [6].

8. CONCLUSION

From the fore-going, there are several evidences that green pesticides are generally safe and effective, although they come with their challenges as already highlighted above. In spite of the seeming shortcomings, green pesticides still remain the attractive option and an alternative for the future. Vendors, consumers and policymakers need to be made aware of the higher quality and safety of products treated with green pesticides. They are equally eco-friendly and extremely biodegradable. Therefore, carry over into food and food products is unlikely, thus reducing food safety risks. This approach looks attractive in solving the issue of incessant pesticide exceedance in food trade involving Africa and Europe.

AUTHORS' CONTRIBUTION

SOF suggested the topic and provided the technical guide. AAA did extensive literature search. Both authors read and approved the final manuscript.

TRANSPARENCY DECLARATION

The authors declare that there is no conflict of interest regarding the publication of this article.

REFERENCES

1. Godfray HCJ, Beddington JR, Crute IR, Haddad L, Lawrence D, Muir JF, et al. Food security: the challenge of feeding billion people. Sci. 2010; 327: 812-817.
2. Carvalho FP. Agriculture, pesticides, food security and food safety. Environ Sci Pol. 2006; 9: 685-692.
3. United Nations 2001. World Population Prospects. The 2000 Revision. Population Division, Department of Economic and Social Affairs. United Nations, NY, 2001.
4. United Nations 2005. World Population Prospects. The 2004 Revision. Highlights. Population Division, Department of Economic and Social Affairs. United Nations, NY. UNEP, 2005.
5. Ngowi A, Mbise T, Ijani A, London L, Ajayi O. Smallholder vegetable farmers in Northern Tanzania: Pesticides, perceptions, cost and health effects. Crop Prot. 2007; 26(11): 1617-1624.

6. Nnamonu LA, Onekutu A. Green pesticides in Nigeria: an overview. J Biol Agric Healthcare. 2015; 5(9): 48-62.
7. Jovanic NZ. Groundwater contamination from pesticides in Africa - a review. In: Yongxin X, Brent U, eds. Groundwater pollution in Africa. London, Imprint CRC Press, 2006: 77-87.
8. Karlsson H, Muir DCG, Teixiera CF, Burniston DA, Strachan WMJ, Hecky RE, et al. Persistent chlorinated pesticides in air, water, and precipitation from the Lake Malawi area, Southern Africa. 2000; 24(21): 4490-4495.
9. Richards NL, Ogada D, Buij R, Botha A. The killing fields: the use of pesticides and other contaminants to poison wildlife in Africa. Reference Module in Earth Systems and Environmental Sciences, 2017.
10. Saltmarsh M. Food safety. Pesticides. Encyclopedia of Human Nutrition. 2010: 323-329.
11. World Health Organization. The WHO recommended classification of pesticides by hazard and guidelines to classification 2004. Geneva, 2005. http://www.who.int/ipcs/publications/pesticides_hazard/en/ (accessed 24 Jan. 2018).
12. Agbohessi TP, Toko II, N'tcha I, Geay F, Mandiki SNM, Kestemont P. Exposure to agricultural pesticides impairs growth, feed utilization and energy budget in African Catfish *Clarias gariepinus* (Burchell, 1822) fingerlings. Inter Aqua Res. 2014; 6: 229-243.
13. Velisek J, Stara A, Machova J, Dvorak P, Zuskova E, Prokes M, et al. Effect of terbutryn and environmental concentrations on early life stages of common carp (*Cyprinus carpio* L). Pest Biochem Physiol. 2002; 102:102-108
14. Primentel D, Levitain LC. Pesticides. Amounts applied and amount reaching pests. Often, less than 0.1% of pesticides applied to crop reach target pests. Bioscience. 1986; 36: 86-91.
15. Barse AV, Chakrabarti T, Ghosh TK, Pal AK, Jadhao SB. Endocrine disruption and metabolic changes following exposure of *Cyprinus carpio* to diethyl phthalate. Pest Biochem Physiol. 2007; 88: 36-42.
16. Singh PB, Singh V. Exposure and recovery response of isomers of HCH, metabolites of DDT and estradiol-17β in the female catfish, *Heteropneustes fossilis*. Env Toxicol Pharmacol. 2007; 24: 245-251.
17. Singh PB, Singh V. Bioaccumulation of hexachlorocyclohexane, dichlorodiphenyltrichloroethane, and estradiol-17b in catfish and carp during pre-monsoon season in India. Fish Physiol Biochem. 2008; 34: 25-36.
18. Palma P, Palma VL, Fernandes RM, Soares AMVM, Barbosa IR. Acute toxicity of atrazine, endosulfansulphate and chlorpyrifos to *Vibrio fischeri*, *Thamnocephalus platyurus* and *Daphnia magna*, relative to their concentrations in surface waters from the Alentejo region of Portugal. Bull Environ Cont Toxicol. 2008; 81: 485-489.
19. Palma P, Palma VL, Fernandes RM, Soares AM, Barbosa IR. Endosulfansulphate interferes with reproduction, embryonic development and sex differentiation in *Daphnia magna*. Ecotox Environ Safety. 2009; 72: 344-350.
20. Palma P, Palma VL, Matos C, Fernandes RM, Bohn A, Soares AM, Barbosa IR. Assessment of the pesticides atrazine endosulfansulphate and chlorpyrifos for juvenoid-related endocrine activity using *Daphnia magna*. Chemosphere. 2009; 76: 335-340.
21. Quinn LP, de Vos BJ, Fernandez-Whaley M, Roos C, Bouwman H, Kylin H, et al. Pesticide use in South Africa: one of the largest importers of pesticides in Africa. In: Pesicides in the modern world. Stoytcheva M, ed. InTechOpen, 2011: 49-96.
22. Mbaye DF. Interdiction de l'endosulfandans les pays du sahelenAfrique de l'ouest. Rapport de consultation, groupe de travail PAN/IPEN sur les pesticides POPs [in French]. Dakar, Senegal, Africa. 2008.
23. Pandey S, Nagpure NS, Kumar R, Sharma S, Srivastava SK, Verma MS. Genotoxicity evaluation of acute doses of endosulfan to freshwater teleost *Channa punctatus* (Bloch) by alkaline single-cell gel electrophoresis. Ecotox Environ Safety. 2006; 65: 56-61.
24. Sithole S, Sauyama I. Status of pesticide management in Southern African Development Community (SADC) in relation to the Rotterdam Convention. Sub-Regional Workshop on Implementation of Rotterdam Convention on the PIC Procedure for Certain Hazardous Chemicals and Pesticides in International Trade; 17-21 February 2003, Windhoek, Namibia. http://pdf.usaid.gov/pdf_docs/Pnact580.pdf (accessed 24 Jan. 2018).
25. Shiyelekeni PP. The status of obsolete pesticides in Namibia. OECD-FAO-UNEP Workshop on Obsolete Pesticides Alexandria, Virginia, USA, 13-15 Sept. 2000. http://www.oecd.org/chemicalsafety/pesticides-biocides/1934511.pdf (accessed 24 Jan. 2018)

26. Mutengwe MT, Chidamba I, Korsten I. Pesticide residue monitoring on South African fresh produce exported over a 6-year period. J Food Prot. 2016; 79(10): 1759-1766.
27. Sani N. Continental workshop on harmonization of pesticide regulations in Africa. 17-19 April 2016, Cairo, Egypt pesticide utilization in Africa: status and trends.
28. Macharia A. 24 best Belly Fat Killaz images on Pinterest Health foods. https://www.pinterest.com/arammacharia/belly-fat-killaz/2016 (accessed 12 April 2018)
29. Canadian center for health and safety. Online. From: https://www.ccohs.ca (accessed: 18 Dec. 2017)
30. Agrow. World agchem market steady. AGROW. 2006; 497(9): 17.
31. Repetto R, Baliga SS. Pesticides and the immune system: the public health risks. World Resources Institute, Washington, DC, 1996.
32. Matthews G, Wiles T, Baleguel P. A survey of pesticide application in Cam. Crop Prot. 2003; 22: 707-714.
33. Partow H. Pesticide use and management in Kenya. Research Memoir no. 92. Institut Universitaired' Etudes du Developement [in French]. Geneva, 1995.
34. Sibanda T, Dobson HM, Cooper JF, Manyangarirwa W, Chiimba W. Pest management challenges for smallholder vegetable farmers in Zimb. Crop Prot. 2000; 19: 807-815.
35. Williamson S, Ball A, Pretty J. Trends in pesticide use and drivers for safer pest management in four African countries. Crop Prot. 2008; 27(10): 1327-1334.
36. Tettey V. Assessment of the use of pesticides by cabbage growers in the Ga District of Ghana. Unpublished B.Sc. Thesis. Department of Home Science, University of Ghana, Legon, 2001.
37. Addo S, Birkinshaw LA, Hodges RJ. Ten years after the arrival of Larger Grain Borer: farmers' responses and adoption of IPM strategies. Int J Pest Manag. 2002; 48 (4): 315-325.
38. Dinham, B. Growing vegetables in developing countries for local urban populations and export markets: problems confronting small-scale producers. Pest Manag Sci. 2003; 59: 575-582.
39. Gale J. South Sudan, UN team up to fight armyworm infestation. http://www.xinhuanet.com/english/2018-01/24/c_136919076.htm (accessed 24 Jan. 2018)
40. Kishi M. The health impacts of pesticides: what do we now know? In: Pretty J, ed. The pesticide detox. Towards a more sustainable agriculture. Earthscan, London, 2005: 23-38.
41. Pretty J, Hine R. Pesticide use and the environment. In: Pretty J, ed. The pesticide detox. Towards a more sustainable agriculture. Earthscan, London, 2005: 1-22.
42. United Nations. 2017 Sustainable Development Goals Report. www.un.org (accessed 14 March 2018)
43. Atuhaire A. Tackling pesticide exposure in sub-Saharan Africa: a story from Uganda. Outl Pest Man. 2017; 28(2): 61-64.
44. European Food Safety Authority, 2015. Chemicals in food. http://www.efsa.europa.eu. (accessed 20 Dec. 2017)
45. RASFF 2014 Rapid Alert System for Food and Feed Annual Report. https://publications.europa.eu/en/publication-detail/-/publication/a2cda8f4-cd64-4604-ab3b-5f8a5f698d50 (accessed 12 April 2018)
46. Akomea-Frempong S, Ofosu IW, Owusu-Ansah, EGJ Darko G. Health risks due to consumption of pesticides in ready-to-eat vegetables (salads) in Kumasi, Ghana. Int J Food Cont. 2017; 4: 13.
47. Christian Aid. Pesticide misuse a major threat to farmers health and food safety. http://allafrica.com/stories/201204200319.html (accessed 24 Jan. 2018)
48. NPA. Northern Presbyterian Agricultural Services and partners, 'Ghana's pesticide crisis: A need for further government action, 2012. http://www.christianaid.org.uk/images/ghanas-pesticide-crisis.pdf (accessed 24 Jan, 2018)
49. Ababio PF, Lovatt P.A review on food safety and food hygiene studies in Ghana. Food Cont. 2014; 06: 04.
50. Omari R, Frempong G. Food safety concerns of fast food consumers in urban Ghana. Appetite. 2016; 98: 49-54.
51. Varo JC, Navarro JC, Amat F, Guilhermino L. Effect of dichlorvos on cholinesterase activity of the European sea bass (*Dicentrarchus labrax*) pesticide. Biochem Physiol. 2003; 75(3): 61-72.
52. Sinyangwe DM, Mbewe B, Sijumbila G. Determination of diclorvos residue levels in vegetables sold in Lusaka, Zambia. Pan Afr Med J. 2016; 23: 113.
53. Musa UF, Hati SS, Mustapha A, Magaji G. Dichlorvos concentrations in locally formulated pesticides (ota-piapia) utilized in Northeastern Nigeria. Scient Res Essay. 2010; 5(1): 49-54.

54. ECPA. 2014 Pesticide use and food safety. European crop protection (accessed 26 March 2018)
55. Taha MEM, El-Zorgani G A, El-Hassan AM, Salghi R. Evaluation of organo-chlorine pesticide residues in human urine from rural population in Sudan J Mater Environ Sci. 2013; 4 (6): 987-992.
56. Ishag AESA, Abdelbagi AO, Ahmed MA, Hammad, EE, Elsaid OE, Hur J-H, Laing MD. Biodegradation of chlorpyrifos, malathion, and dimethoate by three strains of bacteria isolated from pesticide-polluted soils in Sudan. J Agric Food Chem. 2016; 64(45): 8491-8498.
57. Enbaia S, Ahmad M Abusrwil A, Omar AA, Amra HA. Determination of organochlorine pesticide residues in Libyan fish. Int J Curr Microbiol Appl Sci. 2014; 3(10): 198-212.
58. Dasika R, Tangirala S, Naishadham P. Pesticide residue analysis of fruits and vegetables. J Environ Chem Ecotoxicol. 2012; 4(2): 19-28.
59. World Health Organization. Public health impact of pesticides used in agriculture. England: World Health Organization, 1990.
60. Alewu B, Nosiri C. Pesticides and human health. In: Stoytcheva M, ed. Pesticides in the modern world - effects of pesticides exposure. InTech, 2011: 231-250.
61. Sanborn M, Kerr KJ, Sanin LH, Cole DC, Bassil KL, Vakil C. Non-cancer health effects of pesticides. Systematic review and implications for family doctors. Can Fam Physician. 2007; 53: 1712-1720.
62. Mnif W, Hassine AIH, Bouaziz A, Bartegi A, Thomas O, Roig B, Effect of endocrine disruptor pesticides: a review. Int J Environ Res Public Health. 2011; 8: 2265-2203.
63. Gunnell D, Eddleston M, Phillips MR, Konradsen F. The global distribution of fatal pesticide self-poisoning: systematic review. BMC Public Health. 2007; 7: 357.
64. Van Boxstael S, Habib I, Jacxsens L, De Vocht M, Baert L, Van De Perre E, et al. Food safety issues in fresh produce: bacterial pathogens, viruses and pesticide residues indicated as major concerns by stakeholders in the fresh produce chain. Food Control. 2013; 23(1): 190-197.
65. Khush GS. The promise of biotechnology in addressing current nutritional problems in developing countries. Food Nutr Bull. 2002; 23(4): 354-357.
66. James C. ISAAA report finds that global adoption of biotech crops continues to rise. 2011. www.issa.org. (accessed 20 Jan. 2018).
67. Meeusen RL, Warren G. Insect control with genetically engineered crops. Ann Rev Entomol. 1989; 34: 373-381.
68. Schnepf E, Crickmore N, Van Rie J, Lereclus D, Baum J, Geitelson J, et al. *Bacillus thuringiensis* and its pesticidal crystal proteins. Microbiol Mol Biol Rev. 1998; 62: 775-806.
69. Benedict JH, Altman DW. Commercialization of transgenic cotton expressing insecticidal crystal proteins. In: Genetic improvement of cotton: emerging technologies. Science Publishers, Inc., Enfield, NH, USA, 2001: 137.
70. Ismael Y, Bennett R, Morse S. Biotechnology in Africa: The adoption and economic impact of Bt cotton in the Makhathini Flats, Republic of South Africa. Biotechnology conference for Sub-Saharan Africa. Johannesburg, South Africa, 26-27 September 2001.
71. Herring RJ, Rao NC. On the ‘failure of Bt cotton’: analyzing a decade of experience. Econ Pol Week. 2012; 47(18): 45-53.
72. Watch GM. Industry techno-fixes for Bt resistance in pests are counterproductive, 2014. http://www.gmwatch.org (accessed 18 Dec. 2017)
73. Nnamonu LA, Ali AE. Perception of agrochemical use and organic farming in Makurdi, Benue State, Int J Env Prot. 2013; 3(8): 48-52.
74. EPA. 2013. Glossary of terms: methods of toxicity testing and risk assessment. United States Environmental Protection Agency (accessed 26 Jan. 2018)
75. Lale NES. Stored product entomology and acarology in tropical Africa. Mole Publications, Maiduguri, Nigeria, 2002: 204.
76. Okrikata E, Anaso CE. Influence of some inert diluents of neem kernel powder on protection of sorghum against pink stalk borer (*Sesamia calamistis*, Homps) in Nigerian Sudan savanna. J Plant Prot Res. 2008; 48(2): 161-168.