Octa Journal of Biosciences
Octa J. Biosci. Vol. 8(2):83-97

International peer-reviewed journal
July-Dec 2020

Octa Journal of Biosciences
ISSN 2321 – 3663
journal homepage: www.sciencebeingjournal.com

Review Article

Received:16/2/2020 Revised:19/ 8/ 2020 Accepted:29/8/2020 Published on-line: 30/9/2020

Commercialization And Industrialization Through Registration And Use Of Botanical Pesticides For Crop Protection In Zimbabwe: A Review

Nyasha Sakadzo[1]

[1]Department of Soil and Plant Sciences, Faculty of Agriculture, Great Zimbabwe University, P.O. Box 1235, Masvingo, Zimbabwe

*corresponding author e-mail address:nsakadzo87@gmail.com

ABSTRACT

Botanical pesticides have captured a great interest amongst the research community internationally. They have great economic considerations and potential health benefits, but there is lack of regulatory environment in Zimbabwe. The Government of Zimbabwe should enable legal and policy framework so that the use of ethnobotanical pesticides becomes formal and legal. Private and public institutions need to invest in rigorous research to assure policy makers and public about environmental safety and effectiveness of ethnobotanicals. Dedicated procedure for registration and trade is a requirement for botanical pesticides. Agrochemical companies have resources to satisfy regulatory requirements for synthetic pesticides hence they need to do the same on pesticidal plants. The demand for botanical pesticides in Zimbabwe is increasing as most people are into organic farming which is a drive towards climate smart agriculture. In Zimbabwe, several researches have been conducted on various crop protection backgrounds but there is need to review legislations, regulations and policy frameworks for production, marketing and trade of pesticidal plants in Zimbabwe.

Key words: Botanical; legislation; regulations; pesticidal, bio pesticides

1. INTRODUCTION

Ethnobotanical pesticides, are naturally occurring pesticides derived from indigenous plants (Anjarwalla *et al*., 2016). Sola *et al*. (2014) reported that pyrethrum products from *Tanacetum cinerariifolium*, neem products from *Azadirachta indica* and rotenone from *Derris* and *Lonchocarpus spp* as commercial examples of botanical pesticides that have been developed and traded globally. Delvin and Zettel (1999) and Leng *et al*. (2011) recommended the use of pesticidal plants as they are non-persistent with many being UV labile and quicker oxidation by micro-organisms thereby presenting less risk to consumers.

In Zimbabwe, important field pests include aphids (*Brevicoryne brassicae*), red spider mite (*Tetranychus urticae*) and Fall armyworm (*Spodoptera frugiperda*) are dangerous pests which can increase production costs by up to 30% for smallholder farmers (Grzywacz *et al*., 2010), hence the need to use cheaper ethnobotanical pesticides. Post-harvest pests which are most prevalent in storage houses include larger grain borer (*Prostephanus truncatus*, lesser grain borer *(Rhyzopertha dominica*), weevils (*Sitophilus spp*), bruchids (*Callosobruchus spp* and *Acanthosclelides obstecus*) and flour beetle (*Tribolium app*) which attract the attention of using synthetic pesticides (Belmain and Stevenson, 2001; Dhliwayo and Prixley, 2003; Mvumi *et al*., 2003, Musundure, 2015).

Over-reliance on pesticide use has resulted in pests building resistance (Dent, 2000; Mulungu *et al*., 2006; Belmain *et al*., 2013; Parwada *et al*., 2018). Khater *et al*. (2012) postulated that the use of pesticides may kill predators of pests, have residual effects and contamination of underground water sources. Accessibility of agrochemicals for pest, weeds and disease control is restricted to many farmers due to poor distribution networks and

cost. Unscrupulous traders continuously adulterate dilutions which has resulted in pest resurgence. Best alternatives to this disparity are ethnobotanical pesticides which are less harmful to beneficial insects and difficult to adulterate (Amoabeng *et al*., 2013; Okunlola and Akinrinlola, 2014; Mkenda *et al*., 2015, Shiberu *et al*., 2016).

Reports from World Health Organisation (WHO) estimates that 200 000 people are killed worldwide through exposure of synthetic pesticides annually (CAPE, 2009). Research done by UNEP in Sub-Saharan Africa projected that cost of related synthetic pesticides causes poison illness from between 2005 to 2020 could reach US$90 billion (UNEP, 2011). European Union Thematic Strategy on Sustainable use of Pesticides has raised an alarm on use of synthetic pesticides on food which is exported (EU, 2010). Zimbabwe is one of the largest importers of pesticides in Africa hence in the long run, consumers and policy makers will be requiring reduced synthetic inputs in food, hence it will end up being banned in exporting food products to Europe due to improper use of pesticides which may contaminate food (Grzywacz *et al*., 2014; Sola *et al*., 2014; Pavela, 2016).

Reported pesticides problems can be reduced in Zimbabwe by regulating and registration of ethnobotanical pesticides since they have been proven to be effective and environmental friendly (Stevenson *et al*., 2014; Mkenda *et al*., 2015). Pesticidal plants can potentially surmount problems resulting from the use of pesticides as they are cost effective (Mkenda *et al*., 2015; Amoabeng *et al*., 2014). Currently, in Zimbabwe, bio pesticides priority in agriculture is minor as their commercial incentives are low and knowledge about their use is very limited in public, there is limited documentation and scientific evaluation (Chikukura, 2011). There is over-reliance of importation of pesticides hence ethnobotanicals can mitigate this by developing value chain to sell local produced bio pesticides. By doing so, this will encourage innovation and industrialisation. It will support heritage based philosophy 5.0 in line with the Ministry of Higher and Tertiary Education. Zimbabwe is subsidising the use of imported synthetic pesticides which is straining the national budget whilst subsidies can be redirected towards the development of local industry.

United States Environmental Protection Agency found that at the beginning of year 2013, 400 active ingredients and over 1,250 bio pesticides were registered and commercialised in US (USEPA, 2013). Isman (2006) postulated that a small percentage (<0.1%) of bio pesticides are in use. Foerster *et al*. (2001) commented that there is limited information available in application, efficacy and safety of botanical products. African small companies are excluded in research and registration due to high costs. Sola *et al*. (2014) highlighted that there are few manufactures and formulators of pesticides as mostly are located in Asia and Europe.

There is great potential in the use of botanical pesticides in Zimbabwe but their scope in terms of use has remained under exploited as supported by Isman (2006; 2008). Commercialisation of ethnobotanical pesticides is a necessity after regulation and registration has been done. Isman (2015) postulated that, currently, data requirements and guidance documents are being properly adapted for botanical pesticides. Another hindrance to commercialisation of ethnobotanicals is the high cost to the registration of the new products (Amoabeng *et al*., 2014; Pavela, 2014; Dougoud *et al*., 2018).

This paper critically review the need for legislation, regulation and use of botanical pesticides in Zimbabwe. Zimbabwean regulatory authorities are requested to ensure fast track registration procedures of ethnobotanicals products based on justified regulations, promoting the adoption of safer technologies in the development of commercial products. Moreover, regulatory authority should enable agrochemical companies dealing with ethnobotanicals to develop so as to provide growers with reliable products which meet their expectations.

1. Present and future world bio-pesticide market

Bio pesticides should be assessed in the EU using the same assessment of synthetic pesticides. Guidelines should be prepared

so as to facilitate registration of prospective bio pesticides in Zimbabwe. Czjaya *et al*. (2015) commented that; there are fewer bio pesticides active substances registered in the EU than in the US, India, Brazil or China. There is relatively low level of bio pesticide research in the EU due to stiff complexity of EU-based bio pesticide regulations (Balog *et al*., 2017). Shukla and Shukla (2012) and Sola *et al.* (2014) reviewed that global market for pesticides in 2012 was valued at US$1.3 billion and is expected to reach US$3.2 billion by 2018. In 2012, literature points out that North America dominated the global market for bio pesticides accounting for about 40% global demand (Shukla and Shukla, 2012). The global market for bio pesticides is promising and is increasing by almost 10 % every year (Kumar, 2015). Future projections are that the growth of bio pesticides will outplace that of chemical pesticides by an annual growth rates of about 15% (Balog et *al*., 2017). Christas *et al*. (2018) postulated that in the near future, bio pesticides will equalise with synthetics in terms of market size between 2040s and 2050s. The use of bio pesticides has increased popularity in these recent years because they are considered safer than synthetic pesticides. This is supported by Christas *et al*. (2018) who postulated that bio pesticides are naturally less detrimental, decompose quickly without environmental persistence.

2. Ethnobotanical pesticides potential for marketing and scaling in Zimbabwe

As the demand for organic farming is set to increase in support of heritage based philosophy and the vision 2030 implemented by the government of Zimbabwe. Consumers will be demanding safe foods and environmentalists will be recommending eco-friendly pesticides. Anjarwalla (2015) highlighted that pesticidal plants are not readily available to small scale farmers in Africa. This is an opportunity even in Zimbabwe for small holder farmers to raise profiling and access of bio pesticides through low cost processing and marketing. In Zimbabwe, a lot of research has been done on botanical pesticides presenting opportunities for marketing and scaling (Table 1). Sola *et al*. (2014) and Anjarwalla (2015) recommended the development of low cost technologies and value chain where small holder farmers can play a role. There is need to invest in local production and distribution in Zimbabwe so as to increase marketing and scaling.

3. Pesticide Industry of Zimbabwe

Chikanda (1990) reported that there was close to 40 companies which were involved in and marketing up to 450 agro-chemical products belonging to the Agricultural Chemical Industry Association (ACIA). The association is affiliated to the International Group of Pesticide Manufacturers/ Distributors. These organisations have subscribed to observe the International Code of Conduct and Use of Pesticides. Currently, in Zimbabwe, there is no viable industry which is involved formulation and marketing of bio pesticides.

4. The pesticide regulatory environment in Zimbabwe

The author draws from the Zimbabwean Guidelines on the Registration of Pesticides (Ministry of Agriculture, 1983), the Pesticide Regulations, 1971 (Rhodesia Government Gazette, 1991) and the Hazardous Substances and Articles (Protective Clothing: General Regulations, 1984) (Zimbabwe Government Gazette, 1984). All chemicals products imported in Zimbabwe must confirm to health regulations and environmental standards. Registration of such products is done under the ministry of Ministry of lands, Agriculture and Water Development in terms of the Pesticide Regulations of 1977 under the provisions of the Fertiliser Farm Feeds and Remedies Act.

5. Botanical pesticide regulation objectives

Botanical pesticide regulation and registration will ensure that the right chemicals are exported, imported and safely used in Zimbabwe as stipulated in FAO (2015) code of conduct. The overall objective of pesticide regulation ad registration is to protect humans and environment from pesticide risks. Changes in the regulatory and institutional frameworks results in current legislation being outdated. Currently, there are a number of acts or regulations which have been enacted towards the use of pesticides to ensure that the standards are met and adhered to but such regulations are not stipulated concerning the use of heritage based products. Several stakeholders will be involved, Ministry of Agriculture and Water Development, via the Department of

Research and Specialist Services, in conjunction with the Ministry of Health and Child Welfare will be accountable and responsible in ensuring that new botanical pesticides are tested for their efficacy and toxicity for a stipulated timeframe. Registration of bio-pesticides relates to formulation of a product and its active ingredient, it will be intending to have a record of the toxicity of the chemical. The information will be essential in providing remedial action information in the event of an accident.Hazard assessment and concerns for human is done for human and environmental safety. Registration of botanical pesticides will ensure safe and use of bio-pesticides in the interest of user, consumer, general public and vendor.

6. Registration, Legislation and Regulation Instruments Governing Bio pesticide use in Zimbabwe

FAO and WHO (2015) defined pesticide legislation as legal instruments which are specifically designed to control pesticides and went on further to define pesticide regulation with reference to other secondary legislation which further regulate specific areas of the pesticide law which can be issued at ministerial level.FAO and WHO laid down guidelines in 2010 for the registration of Pesticides as source of information for establishing or revising a national pesticide registration system. These were supplemented by the FAO/WHO Guidelines on Data Requirements for the Registration of Pesticides in 2013 as postulated by FAO (2015). There is need to update legislation, registration and regulatory environment for bio pesticide use in Zimbabwe. This will ensure effective connections between pesticide legislation and other relevant legislation with minimal contradiction. Updating pesticide legislation will help nations to comply with the requirements of international protocols and recommendations.

Currently, there are two acts of Parliament that form the regulatory environment for pesticide regulation in Zimbabwe. The first one is the Fertiliser, Farm Feeds and Seeds and Remedies Act (Chapter 186, Section 24). This act is effected through the Ministry of Agriculture with the Plant Protection Research Institute, in the Department of Research and Specialist Services, as the regulatory agency. There are set of regulations under this act: The Pesticide Regulations 1977, it defines and stipulate regulations and process of registration, experimentation, storage, distribution, labelling and selling of pesticides. There is need to tally this Act with that one of bio pesticides. The second Act is the Hazardous Substance and Articles Act (Chapter 322, Section 47). This act is administered through the Ministry of Health. The Drugs Control Council is the regulatory agency. In terms of The Act, Statutory Instrument 313 of 1981 on Hazardous Substances and Articles (Group 11: General) Regulations, 1981 is intended to ensure the safe use of pesticides. The registration entails that only the right types of chemicals are imported and exported outside Zimbabwe. This is effected by the Environment Management Act of 2002.

7. Bio pesticide Registration Process

The process of registration should be the same as that of pesticides, the process of registration should be spearheaded by the pesticide registration board in conjunction with other expertise from the national and agencies dealing with various aspects of pesticide management. This ensures broad representation of relevant disciplines for risk assessment. The Botanical pesticide registration board in Zimbabwe should include relevant staff from the ministry of Agriculture, health (expertise on vector control, pesticide residues in food and on occupational and bystander as indicated in the manual of International Code of Conduct (FAO, 2015). Environmental expertise on fate of pesticides in the environment and toxicity for fish, birds, bees etc), The Botanical registration board may also further include representatives from the ministry of transport which transport dangerous goods; labour (occupation health and safety; trade and other important government academic or research institutions. The law of Zimbabwe establishes how the board members are appointed, ministries and agencies to be represented and those involved in decision making.

Representatives of the company manufacturing the ethnobotanicals are the ones who makes the application in accordance with the Zimbabwean regulations. The application for the registration must be made in triplicates to the registering officer. Attached to the applications where applicable: advertisement text to be used in promoting the sale of the pesticide, two samples of the ethnobotanical products- the amount being specified by the Registering Officer, information on efficacy and toxicity. Proposed label will supply information on the

chemical from published sources of literature and such data will be used in assessing validity of claims. Labels are supposed to be printed in three official languages used in Zimbabwe namely; Shona, Ndebele and English. Physical properties and toxicology information may be accepted from recognised published sources. The agricultural department considers acceptance of claims for the control of agricultural and horticultural pest in similar climates to Zimbabwe. Experimental data in support of the claims will be obtained from experimentation stretching over at least two and preferably three different climate conditions of Zimbabwe where the ethnobotanical is likely to be used. Registration is completed when the applicant is issued with a Certificate of Registration. Zimbabwe can update its pesticide registration scheme by going through FAO/WHO Guidelines for The registration of pesticides (2010) as useful source of information for updating or establishing a national pesticide registration scheme. These guidelines are supplemented by the FAO/WHO Guidelines on Data Requirements for the Registration of Pesticides (2013).

8. Ethnobotanical use information system, safety and health education

Agro chemical companies and companies in the agricultural chemical industry promote the safe use of bio pesticides through courses for end users, publication of pamphlets and posters on ethnobotanical products. The Agricultural Chemical Industry Association liases with the Government in policing safety rules designed to target users of agricultural chemicals as well as consumers of agricultural products. There is need for training courses to educate agricultural bio pesticides users no become safety conscious. The Government of Zimbabwe encourages the individual companies to simplify posters as regards formulation, application rates, safety precautions in terms of storage and procedures to be followed in case of poisoning. Kujeke (1994) stated that sales representatives of agro-chemicals and agricultural extension officers are major sources of information on pesticide products and use for farmers in Zimbabwe. Other sources are printed materials, ethnobotanical pesticide labels and mass media. For the communal areas, fielding and training programmes will be conducted by the AREX officers.

9. Environmental concerns

Dougoud *et al*. (2019) pointed out that thorough assessments of bioaccumulation have not been done. Environmental concerns and risks associated with the use of botanical insecticides as recommended by WHO and FAO (2013; 2016) should be part of the registration process. El-Wakeil *et al*. (2013) concluded that neem toxicity is usually significantly lower than thet of synthetic pesticides although some non-target species may be affected. Amoebang *et al*. (2013) and Mkenda *et al*. (2015a) also found that botanical extracts had lower impacts on non-target ladybirds. Greater part of the researches done on environmental concerns highlighted less effects on non-target species, however the use of *Tephrosii* for poisoning fish illustrates the risk associated with botanical insecticides as reviewed by Nuewinger (2004) and Pubchem (2013). Crops can be harvested without the risk of residual effects due to rapid breakdown of naturally occurring compounds when exposed to UV light and micro-organism in soil/water (Isman, 2000; Angioni *et al*., 2005; Caboni *et al*., 2006; Tembo *et al*., 2018, Dougoud, 2019). This reflect that bioactive compounds from the plants decompose into harmless natural products as compared to synthetic compounds that persist in and on plants for weeks, months and years in soil (Damalas and Koutroubas, 2015; Dougoud *et al*., 2019).There is need for assessment of health and environmental concerns in using botanicals.

11. Safety on handling Botanical insecticides

FAO and WHO (2013, 2016) recommended that exposure of farm workers, applicators and residual effects on crop should be evaluated to determine acceptability of risks associated with the use of pesticides. Most of the researches done on botanical pesticides are laboratory evaluations so laboratory safety assessments are difficult to extrapolate to real life situations as highlighted by Dougoud *et al*. (2019). Concentration of extracts may be low but exposure during processing has not been evaluated, this has resulted in some countries legally allowing the use of botanical extracts for non-commercial farming (Belmain and Stevenson, 2001; Klein *et al*., 2015). Dougoud *et al*. (2019) cited several authors who have published several article with argumentative debate on safety assessments of botanical pesticides. Some authors argue that botanical extracts have

mammalian toxicity whilst others have little or no intoxications (Belmain *et al*., 2012; Isman, 2008). Botanical pesticides are said to have short re-entry intervals which guarantees safety to the applicant (Stoneman, 2010). Hamudikuwanda *et al*. (2012 evaluated the toxicity of the pesticidal plants *Strychnos spinosa* Lam., *Bobgunnia madagascariensis* (Desv.) J.H. Kirkbr and Wiersama *Vernonia amygdalina* Del. and *Cissus quadrangularis* in mice.Toxicity evaluations of existing pesticidal plants is required in Zimbabwe so as to ensure safety during harvesting, processing and handling. There is need to make use of the principle of precautions during processing and handling of botanical extracts.

12. Sustainable utilisation of pesticidal plants

Zimbabwe Smallholder farmers need to be educated in the use of sustainable utilisation of plants which have proven to have pesticidal properties. Pesticidal plants need to be conserved, managed, domesticated and used sustainably. Overharvesting of pesticidal plants in the wild can lead to biodiversity loss. Cultivation and propagation of pesticidal plants must be documented in manuals from the Department of Research and Specialist Services and Plant protection. Khumalo *et al*. (2006) recommended the use of current existing guidelines to prevent extinction of indigenous resources. Botanical pesticidal plants can be suitably incorporated into integrated crop protection management so as to reduce the amount of chemicals used to control pests (Sesan *et al*., 2015). Botanical products are eco-friendly, easily degradable and does not pollute the environment as compared to synthetic pesticides (Leng *et al*., 2011). Botanical pesticides are said to have a very short pre-harvest intervals so this makes them safe to use on fresh fruits and vegetables (Khater, 2012).

13. Researches on use of botanical pesticides in Zimbabwe

Several studies have been conducted in Zimbabwe as exhibited in table below (Table 1). This is an achievement which enables the speeding up of legislation, regulation and use of botanical pesticides in Zimbabwe. There is need for multi environmental trials to test the existing pesticidal plants which have proven to be efficacy towards selected pest species.

Table 1: Some of selected research work conducted on the use of botanical pesticides in Zimbabwe

Species name	Common name	Reference
Allium sativum	Garlic	Ngaufe and Kugedera, 2019
Aloe ferox	Cape aloe	Natural Resources Insitute,2010
Aloe vera L.	Aloe vera	Sakadzo and Chibi (2020)
Annona stenophylla subsp.cuneata	Dwarf custard apple	Berger, 1994
Bobgunnia madagascarensis	Snake bean	Natural Resources Institute,2010, Nyahangare *et al*. (2012),Hamudikuwanda *et al*. 2012
Capsicum annum	Hot pepper, Chillies	Ngaufe and Kugedera (2019)
Capsicum frutescens		Moyo *et al*. 2006
Cissus quandrangularis	Velvet grape	Hamudikuwanda *et al*. 2012, Natural Resources Insitute, 2010, Nyahangare *et al*. (2012)
Combretum imberbe	Lead wood	Natural Resource Institute, 2010, Chikukura *et al*. 2011
Datura stramonium	Thorn apple	Page, 1997, Sakadzo *et al*. (2018)
Derris elliptica	Poison vine	Moyo *et al*. (2016)
Eleusine corocana	Finger millet chaff	Makaza and Mabhegedhe,2016
Eucalyptus spp	Gum tree	Musundure*et al*. 2014, 2015,

		Muzemu *et al*. 2013, Machingura, 2014, Mandudzi and Edziwa, 2016, Makaza and Mabhegedhe, 2016 Parwada *et al*. (2018)
Helianthus annuus	Sunflower	Makaza and Mabhegedhe,2016
Lantana camara		Furusa,2008, Parwada *et al*. (2018)
Lippia javanica	Fever tea	Natural Resources Institute, 2010, Katsvanga and Chigwaza (2004). Gadzirai *et al*. 2006, Chikukura *et al*. 2011, Muzemu *et al*. (2012), Madzimure *et al*. (2011), Chikukura, 2011, Makaza and Mabhegedhe (2016)
Melia azedarach	Persian lilac	Makaza and Mabhegedhe,2016
Nasturtium trapaeolum		Mwale *et al*. (2006)
Neorautanenia brachypus		Murungweni, 2012
Nicotiana tabacum	Tobacco	Sakadzo *et al*. 2020
Ocimum basilicum	Sweet basil	Makaza and Mabhegedhe,2016
Rapanea melanophloeos	Cape beech	Makaza and Mabhegedhe,2016
Solanun spp		Natural Resources Institute, 2010, Muzemu *et al*. 2012 Nyahangare *et al*. (2012), Madzimure *et al*. 2011, 2013
Spirostachys africana	Tamboti	Mvumi *et al*. 1995, Chikukura *et al*. 2011, Makaza and Mabhegedhe,2016
Strychnos spinosa	Spiny monkey orange	Hamudikuwanda *et al*. 2012, Nyahangare *et al*. (2012), Madzimure *et al*. (2013)
Tagetes ereca	African marigold	Moyo *et al*. (2006)
Tagetes minuta	Mexican marigold	Kutsvangwa and Chigwaza (2004),Natural Resources Institute, 2010, Muzemu *et al*. 2013, Parwada *et al*. 2018 Sakadzo and Chisvuure, 2020
Tephrosia vogelii	Fish poison bean	Natural Resources Insitute, 2010, Parwada *et al*. (2018)
Vernonia amygdalina	Bitter leaf	Nyahangare *et al*. (2012)
Vernonia amygdalina		Hamudikuwanda *et al*. 2012

14. Effects of International bans and restrictions on pesticide use in agriculture industry

In Europe and United States there is increased awareness of health and environmental hazards of agro chemical use so as to improve food quality and safety. This will results in restricted legislation on pesticide use in Africa as a whole. Zimbabwe as one of the largest importers of pesticides. World Health Organisation (WHO) estimates that 200 000 people are killed worldwide through exposure of synthetic pesticides annually (CAPE, 2009; Sola *et al*., 2014). UNEP did a research in Sub-Saharan Africa and projected that cost of related synthetic pesticides poison illness between 2005 and 2020 could reach US$90 billion (UNEP, 2011). Zimbabwe will end up being banned in exporting food products in the long run on which pesticides were used to Europe. Strict regulations were set out by the European Union (EU) regarding levels of pesticide residues and safety of horticultural produce exported to their markets. It banned the export of vegetables containing dimethoate. Consignments of vegetables containing chemical residues above the required limits are rejected and destructed (Business Daily, 2014).The European Union imposed

that the Maximum Residue Levels (MRLs) should not exceed 0.001mg/Kg. Several smallholder farmers opted out of the export business hence negatively affecting their livelihoods as they are major producers of vegetable crops (Daily Nation, 2014; Lengai *et al*., 2018).The concern is on the implication for horticultural exports as strict regulations on pesticide will affect many stakeholders. Currently, there is little research on the welfare effects of restricting pesticide use on farm products. Counterfeit to this is to invest much in botanical pesticide legislation and regulation in Zimbabwe.

15. Limitations to uptake of botanical pesticides in Zimbabwe

Data on efficacy of botanical pesticides is obtained from bioassay trials whilst field trials are very rare (Okunlola and Akinrinnola, 2014). Shiberu *et al*. (2016) pointed out that higher doses of pesticidal plants are required for their efficacy under field conditions which requires more labour during harvesting and processing. Botanical pesticides require frequent application as their efficacy is short lived as compared to synthetic pesticides (Dougoud *et al*., 2019, this requires repeated applications resulting in farmers opting for synthetic pesticides. There is still a research gap in terms of appropriate technology, especially the oils and dust formulations (Lale, 2002). Mode of action of current pesticides has not been proven in existing agro-ecological zones of Zimbabwe. Botanical formulations are not currently available in commercial quantities on the counter so some farmers cannot have access as pointed out by Stoneman *et al*. (2010).Data on chemistry, toxicity, packaging is currently not readily available hence prolonging their registration (Gupta and Dikshit, 2010).Research is failing to bring pesticidal plants from the wild to the shelves for marketing as only laboratory experiments are being done which does not represent the reality under field conditions (Dougoud *et al*. (2019). Shelf life is another constraint to farmers since it relies on several factors such as temperature and moisture which might be difficult to control as highlighted by Koul (2011). Currently, selling of pesticidal plants is facing challenges currently due to lack of data on efficacy, safety, toxicity, persistence, shelf life, inconsistent performance of crude extracts, lack of standardisation and documented application protocols (Sola *et al*., 2014, Anjarwalla *et al*., 2015; Anjarwalla *et al*., 2016). There is need for awareness about botanical pesticides to small scale farmers, stakeholders and policy makers.

16. Practicality and profitability of using botanicals

There is need for economic analysis to determine the economic viability and practicality of using botanical insecticides in Zimbabwe. Researches have been done in Africa and economic analysis reviewed that botanical pesticides are more cost beneficial for smallholder farmers than using synthetic pesticides as inputs costs, little yield loss and trade-off are reduced (Amoabeng *et al*., 2014;Mkenda *et al*.,2015; Tembo *et al*., 2018; Dougoud *et al*., 2019). Production, harvesting and processing of botanicals requires a heavy workload as compared to synthetic pesticides (Dougoud *et al*., 2019). Findings by (Gupta, 2005; Gupta and Pathak, 2009, Mkenda *et al*., 2015a; Dougoud *et al*., 2019) indicated that, the total costs of using botanical extracts are substantially lower as compared to applying synthetic insecticides. Several studies documented profitable/ cost benefit ratios of using neem homemade botanical insecticides (Rajappan *et al*., 2000; Aziz *et al.*, 2013; Gupta, 2005, Narasimhamurthy and Ram, 2013; Okrikata *et al*., 2016). Dougoud *et al*. (2019) highlighted that the economic viability of botanical insecticides on certain plant species is less documented. Some reviewed studies indicated profitable use of botanical insecticides (Amoabeng *et al*., 2014; Mkenda *et al*., 2015; Okrikata *et al*., 2016).

17. Future prospects

Involvement of various stakeholders which include, universities, researchers, NGOs and the government of Zimbabwe is a need to facilitate the development, manufacturing and sale of eco-friendly alternatives. The Department of Research and Specialist Services in conjunction with agrochemical companies such as Zimbabwe Fertiliser Company (ZFC) must research on formulation to enable commercialisation of ethnobotanicals for crop protection. Regulations, marketing and use of ethnobotanicals is required so as to encourage commercialisation of low risk compounds in Zimbabwe.

There is need to encourage indigenous private sectors to participate in formulation, testing and marketing pesticidal plants. Government should make favourable policies to govern processing, harvesting, propagation and use of botanical

pesticides. Timeframe of registration of pesticidal plants should be less than that for synthetic chemicals. The government of Zimbabwe should design policies to encourage and protect local companies that may be involved in the processing and marketing of pesticidal plants so that people benefit from local natural resources. There is need for policies that do away with indiscriminate harvesting of pesticidal plants which results in environmental degradation. Department of Research and Specialist Services which is under the plant protection unit should be involved in aggressive awareness campaigns through utilisation of media. Future research must put more focus on toxicity levels, active compounds and their integration with other pest, disease and weed management programs. This will enable formulation and commercialisation in Zimbabwe. Researchers in Zimbabwe must work with the Department of Research and Specialist Services to produce stable and durable formulations of botanical pesticides against climatic factors. They should embark on efficacy evaluations, mode of action, human and environmental assessments risks.

CONCLUSIONS

Best alternatives to synthetic pesticides are botanical pesticides as synthetic chemicals have raised a lot of concerns due to negative effects on human health, environment, beneficial organisms and balance of the ecosystem. Botanical pesticides have low toxicity, low environmental persistence and higher biodegradation. The issues raised on ethnobotanical pesticides are not exhaustive but provide indicators for further research for detailed analysis of bio pesticide use and policies in Zimbabwe. Pesticidal plants are vital in contributing safe food exports. Continued research on how agricultural productivity and performance could be enhanced with the use of botanical pesticides is required. There is need for sound bio pesticide regulations that allows firms to operate without undue regulatory controls, this will prevent environmental pollution and endangering public health. Ethnobotanical plants may contribute immensely to food production and livelihood enhancement. In Zimbabwe, the elders who are well familiarised with the use and conservation of pesticidal plants are vanishing without any proper documented guidelines. The government of Zimbabwe should promote policies which facilitates the use of ethnobotanicals through commercialisation at village level using crude extracts for large scale production. Researchers in Zimbabwe recognise the use of pesticidal plants as cost effective to manage pests and they are keen to research more in their use and efficacy. There is need for multistakeholder engagement so as to improve regulation and registration policies in Zimbabwe.

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ACKNOWLEDGEMENTS

The author would like to acknowledge Great Zimbabwe University colleagues and friends for the support they rendered to me during the preparation of this paper.