SUSTAINABLE AGRICULTURE TANZANIA AND ECOLOGICAL ORGANIC AGRICULTURE

SOURCE: PLANTWISE BLOG

REPORT ON SOURCE, PREPARATION, DOSAGE, APPLICATION METHODS, STORAGE, MODE OF ACTION AND EFFICACY OF DIFFERENT BOTANICAL PESTICIDES

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In the process of developing this assignment, I might have happened to disappoint someone in a way or another, I would like to sincerely register my apologies for any inconveniences.

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SOURCE, PREPARATION, DOSAGE, APPLICATION METHODS, STORAGE, MODE OF ACTION AND EFFICACY OF DIFFERENT BOTANICALS

INTRODUCTION

Pests (arthropod pests, diseases and weeds) management is one of very crucial aspects in the crop production systems. The use of conventional pesticides in managing pests has been associated with various serious detrimental effects, not only to the environmental and ecosystem, but also on the humans and other living things.

Increasing demand to the environmental conservation coupled with healthy concerns and the need for safer foods has been a driving force to the development of alternative approach to pest management in agriculture.

According to Dougoud *et al*. (2019), homemade botanical insecticides are widely used by subsistence and transitional farmers in low-income countries. Their use is often driven by the limited availability or cost of commercial pesticides.

Hence development of botanical pesticides obtained from plant materials has been considered to be alternative to conventional pesticides, particularly in ecological organic agriculture and sustainable agriculture systems.

The application methods, efficacy, mode of action and storability of the botanicals are some of the critical issues requiring more attention for the development of the industry.

Ngegba *et al.* (2022) reported that, botanical pesticidal constituents are effective against myriads of destructive pests and diseases. More importantly, they are widely available, inexpensive, accessible, rapidly biodegradable, and have little toxicity to beneficiary agents. The phytochemical compositions in diverse plant species are responsible for their varying mechanisms of action against pests and diseases. However, difficulties in their formulation and insufficient appropriate chemical data have led to a low level of acceptance and adoption globally.

Research has been done to different plant species and different parts of the plants to ascertain their effectiveness in managing different pests attacking different crops.

This review explores attributes of botanical pesticides to foster their development for enhanced availability and use to ensure safer food production, improve ecological organic agriculture and heighten sustainable ecosystem.

SOURCE (PLANT SPECIES AND PLANT PART), PREPARATION (+ RECIPES)

PLANT SPECIES AND PLANT PARTS USED TO MAKE BOTANICAL PESTICIDES

Botanicals are prepared from different plant species, singly or in a combination of two or more plant species. According to PlantwisePlus Blog (2019), twelve botanicals recommended by national extension partners in 20 countries within the global agricultural Plantwise program include the following: garlic (*Allium sativum*), neem (*Azadirachta indica*), chili pepper (*Capsicum spp*.), Siam weed (*Chromolaena odorata*), mother of cocoa (*Gliricidia sepium*), chinaberry (*Melia azedarach*), moringa (*Moringa oleifera*), tobacco (*Nicotiana tabacum*), clove basil (*Ocimum gratissimum*), tephrosia (*Tephrosia vogelii*), tree marigold (*Tithonia diversifolia*), and bitter leaf (*Vernonia amygdalina*).

Dadang *et al*. (2009) evaluated the efficacy of two botanical insecticide formulations, mixtures of *Piper retrofractum* (Piperaceae) and *Annona squamosa* (Annonaceae) (RS) extracts and *Aglaia odorata* (Meliaceae) and *A. squamosa* (OS). They reported that, the application of both RS and OS formulations decreased the population of Crocidolomia pavonana (F.) (Lepidoptera: Pyralidae) and *Plutella xylostella* (L.) (Lepidoptera: Yponomeutidae) and the treatments of RS and OS at 0.1% was more effective than synthetic insecticide. The plant parts used by Dadang (2009) in the experiment were seeds of *Annona squamosa* (Annonaceae), twigs of Aglaia odorata (Meliaceae), and inflorescences of *Piper retrofractum* (Piperaceae).

Ahmad *et al*. (2018) compared insecticidal efficacy from six commonly grown plants of Pakistan, viz. *Allium sativum* (garlic - Alliaceae), *Zingiber officinale* (ginger - Zingiberaceae), *Cymbopogon citratus* (lemon grass - Poaceae), *Eucalyptus globulus* (Myrtaceae), *Nicotiana tabacum* (Tobacco - Solanaceae), and *Azadirachta indica* (Neem - Meliaceae) against *Tribollium castaneum* infesting stored wheat, rice, corn and gram pulse. Various plant parts were dried, powdered, and used as admixtures to the stored commodities. The results suggested that *A. sativum* (garlic) and *Z. officinale* (ginger) were more effective resulting into 15 times higher adult mortality and 4 to 5 times reduction in grain weight losses when mixed with rice grains. Similarly, *A. indica* when admixture with wheat checked the population growth in the resources resulting into 3.5 times less adult production compared to controls. The plant parts used in this work are obviously cloves (garlic), rhizomes (ginger), and leaves (tobacco and lemon grass).

According to Kamatenesi-Mugisha (2013), people living around the Lake Victoria region use plant extracts, parts and powders to protect stored food commodities from insect pests. The widely used plants species are *Ocimum gratissimum*, *Tithonia diversifolia*, *Eucalyptus saligna*, *Eucalyptus globulus* and *Cupressus lusitanica.* Tavares *et al*. (2021) reported that *Azadirachta indica*, *Capsicum annuum*, *Nicotiana tabacum* and *Tagetes erecta* are the most researched plants and have the potential to be viable options in the pest management approach.

Amoabeng *et al*. (2019) found that fifteen plant families have species that have been exploited for their insecticidal properties. Three families, Apiaceae, Asteraceae and Lamiaceae, have the largest number of species that have been used for both habitat manipulation and botanical insecticides. Dhale (2013) reported that a total of 80 plants belonging to 39 families have been documented for their insecticidal or pesticidal

potential. Of these, families with more number of species used as insecticide or pesticide are, Fabaceae with 9 species; Lamiaceae with 8 speceis; Euphorbiaceae and Asteraceae with 5 species. Okunlola and Akinrinnola (2014) reported that, the most prominent among the materials used in the preparation of some of the identified botanical formulations are *Azadirachta indica* (Neem) leaves, *Piper guineense* (Black pepper), and *Nicotiana tobaccum* (tobacco). These plants were combined together in the preparation of botanical formulations to prevent and/or control pest in the field.

Given the huge number of plant families and different many species within each family, with varied morphological features for each species, then it is straight forward that, botanical pesticides can be prepared from a wide range of plant parts. As Lengai *et al*. (2020) explained, plant parts used to make botanical pesticides include barks, leaves, roots, flowers, fruits, seeds, cloves, rhizomes and stems. The plant part used is dependent on the targeted bioactive compounds and their abundance within that particular part. It is worth noting that, in one plant species, different parts of the same plant may yield the same or different bio pesticide compound as the case for neem plant.

PREPARATION AND RECIPES FOR BOTANICAL PESTICIDES

Botanical pesticides are processed from different parts of the plant. Depending on the form of the pesticide product to be developed, the procedures can be different. Availability of the facilities for preparation of the botanical pesticide can also influence the nature of preparation. Karani *et al.* (2017) reported that, botanical pesticides can be prepared in different forms such as powder, liquid formulation including water extract, crude oil extract, ethanol extract, aqueous extract or commercial formulation. Experimental or commercial preparation may vary greatly with the preparation of homemade botanical pesticides.

PREPARATION OF HOMEMADE BOTANICAL PESTICIDES

Peace Corps developed Standard Procedures for the Preparation and Application of Homemade extracts as outlined below:

Standard Procedures for the Preparation and Application of Homemade Extracts

1. Use utensils for the extract preparation that are not used for food preparation, for drinking, or as cooking water containers. Clean all the utensils thoroughly after using them.
2. Do not have direct contact with the crude extract while in the process of preparation or during application.

3. Make sure to place the extract out of the reach of children and house pets when leaving it overnight.
4. Harvest all of the mature and ripe fruits from any plant before extract application.
5. Always test the extract formulation on a few infected plants before going into large-scale spraying.
6. Wear protective clothing while applying the extract.
7. Wash hands after handling the extract.

Some botanical plants and recipes as described by Peace Corps are presented in Table 1 below:

Table 1. Some botanical pesticides and recipes

	Description	Recipe
1.	**Hot Pepper Solution**: A general repellent, it is effective for caterpillars, cabbage worms, ants, aphids, beetles, and cutworms	Finely chop 15 peppers and add 1 liter of water. Steep for 24 hours, strain, and apply.
2.	**Onion Brew** It repels a variety of insects, including ants, aphids, army worms, and especially borer insects such as caterpillars.	Finely chop 4 cups of onion and add to 2 liters of water. Steep for 24 hours, strain, and apply. Best used when fermented.
3.	**Garlic Brew** It repels many insects, including ants, aphids, and caterpillars, as well as nematodes.	Finely chop one-half cup of garlic and add to three-fourths liter of water. Soak for 24 hours, strain, and apply to plant and surrounding soil.
4.	**Mint (Mentha)** It can be used as a repellent against aphids, cabbage pests, and flea beetles, as well as against bacterial diseases.	Cut fresh mint leaves and citrus (orange or lemon) peels to make a repellent. Place the pieces in a small pan covered with water, and bring to a boil. Soak overnight and apply during the evening watering.
5.	**Tomato-Leaf Spray** This is a particularly effective repellent for aphids and caterpillars, but should not be used on tomatoes, eggplants, peppers, or potatoes.	Pack 1 quart (approx.1 litre) of tomato leaves in a sturdy, heat-resistant bucket. Pour 1 quart of boiling water over the leaves, and let the mixture steep for one hour. Next, strain the mixture through a cloth, squeezing the leaf dregs to remove as much liquid as possible. Dilute the mixture with water before using.
6.	**Neem's extracts** have an effect on nearly 400 species of insects, including major pests (moths, weevils, beetles, and leaf miners). The most effective insecticide comes from the seed, but the leaves can also be used. These extracts do not kill	Dry leaves in shade, as UV rays from the sun break down azadirachtin, their principal chemical compound. When leaves are dry, pound and mix a generous handful of the powder with 10 liters of water. Let steep for 12

	insects directly but effectively prevent their reproduction.	to 24 hours. Strain and apply during the evening watering.
7.	**Gliricidia (*Gliricidia sepium*)** Gliricidia is a wonderful tree for soil amelioration due to its ability to fix nitrogen. Its leaves can also provide an insecticide that is effective on both chewing and boring insects.	There are two ways to use Gliricidia. First, pick leaves and place near plants to be protected. When they become dry, remove or leave as mulch, and reapply fresh ones. Second, pound a generous amount of leaves, add a small amount of water, and soak for 24 hours. Strain and apply during the evening watering
8.	**Tobacco (*Nicotiana tabacum*)** Tobacco contains nicotine, which can be used as a potent insecticide. (Be careful, as nicotine is a poison and high concentrations can be lethal.) Target organisms include aphids, cabbageworms, caterpillars, flea beetles, grain weevils, leaf miners, mites, stem borers, thrips, rust, some fungi, and leaf-curl virus. Note: Do not use on tomatoes, eggplants, peppers, or potatoes.	First, dry and pound the leaves. Add 20 grams of tobacco to 1 liter of water, soak overnight, and apply during the evening watering

According to Zero Waste Centre (2021), the following are recipes for botanical pesticides from neem and papaya leaves as presented in Table 2.

Table 2: Botanicals and recipes for neem and papaya leaves

	Description	Recipes
1.	**Neem leaves pesticide** Neem pesticide can be used to control caterpillars, grasshoppers, whitefly, and aphids.	-Take 500 gram of neem leaves, wash it and chop it for a faster result. -Mix it with 5 liters of water. -Put the mixture in the jerry can and let it ferment for around 14 days. -To make sure that the solution is ready, see if the cap of the jerry can is bulging.
2.	**Papaya leaves pesticide** Papaya leaves contain an active ingredient called “Papain”, that is known to effectively control caterpillars and sucking pets. It can control termites, aphids, caterpillars and various insects.	-Take 500 gram of neem leaves, wash it and chop it for a faster result. -Mix it with 5 liters of water. -Put the mixture in the jerry can and let it ferment for around 14 days. -To make sure that the solution is ready, see if the cap of the jerry can is bulging.
Note: -Addition of 50 grams detergents to make it stronger is optional. -Just mix everything before the fermentation process. -just spray it to the infected parts. -The pesticides are used as control treatment rather than prevention.		

In their nursery manual, World Agroforestry Organization provides appendix with recipes and preparation of botanical pesticides. They recommend that, when preparing a pesticide from plants, always let them dry in the shade, because direct sunlight could break down the active ingredients. Further, suggested that, adding a little soap will help the liquid adhere to the plants and that when applying, wet both sides of the leaves. Table 3 presents a summary of recipes and preparation of some botanical insecticides and fundicides according to World Agroforestry.

	PLANT USED	PREPARATIONS / RECIPES
INSECTICIDES		
1.	**Neem:** It has been used effectively on over 100 leaf-eating insects.	Collect mature seeds, wash and remove the husk, and allow to dry completely. Take twelve handfuls of dry seeds (or use 500 grams per 10 litres water) and grind them into a fine powder. Mix the powder in 12 litres of water and soak overnight. Strain the liquid and apply.
2.	Annona (custard apple and soursop - *Annona squamosa, A. muricata*).	Collect two handfuls of seeds and dry. Grind into a fine powder. Mix with 4 litres of water and soak overnight.
3.	Chile, pepper (Capsicum frutescens).	Collect two handfuls of chillies and dry. Grind into a fine powder, taking care not to inhale too much of the highly irritating dust, mix with 2 litres of water and soak overnight.
4.	Tabaco, tobacco (*Nicotiana tabacum*). Only real tobacco contains nicotine, the substance acting as an insecticide.	Collect healthy, fresh leaves which are free of spots. Mix 80 grams of dry leaves and stems per litre of water and soak for two days. Best if applied in the early morning because the solution is very volatile — it escapes as a gas. CAUTION: Tobacco is toxic to people, do not breath the vapours, or allow to touch the skin.
5.	Piretro, pyrethrum (*Chrysanthemum cinerariifolium*). The active ingredient is found in the flowers.	Collect only fully opened flowers. Mix 100 grams of dried flowers in 1 litre of water and soak for one day. Can be stored for up to two months, but strain it first.
6.	Rícino, castor bean (*Ricinus communis*). Leaves and stems can be	Mix 300 grams of dry plant material for every 1 litre of water and soak for one day. The active ingredients rapidly disintegrate, therefore the insecticide must be

	used, but the seeds are the most effective part.	applied frequently and with fresh solution each time. Also works as a nematicide and fungicide.
7.	Mata ratón, cacaute, gliricidia (*Gliricidia sepium*).	Roots, seeds and leaves are poisonous to rats and other small animals. Also an insecticide against aphids.
8.	Ajo, garlic (*Allium savitum*).	Finely chop 3 bulbs of garlic and mix with 10 litres of water. You can store this for up to two weeks unstrained, although its effect on the plant lasts only for one to three days after applying it.
FUNGICIDES		
1.	Papaya (*Carica papaya*).	Finely chop 1 kg of dry leaves and mix with one litre of water; stand overnight. Dilute with four litres of water.
2.	Ajo y cebolla, garlic and onion. (*Allium sativum, A. cepa*).	Mix 500 grams finely chopped material in 10 litres of water. Allow to ferment for one week. Dilute with another 10 litres of water. Incorporate into the soil.
	Canavalia (*Canavalia sp*.).	Canavalia has been shown to kill the nests of leaf-cutter ants. The ants do not eat the leaves they cut, but use the leaves to grow a fungus which the ants eat. Canavalia leaves prevent the fungus from growing, and this starves the ants.

EXPERIMENTAL OR COMMERCIAL BOTANICAL PESTICIDES PREPARATION

Under laboratory studies and experiments methods for preparation of botanical pesticides are much more complicated and more precise to cater for scientific requirements. Similary, for industrial / commercial production manufacturers must comply with relevant required standards. In an experiment, Purkait *et al*. (2019) developed Emulsifiable Concentrate (EC) formulations from seed oils of Pongamia *pinnata* L., *Pachyrhizus erosus* L. and *Annona squamosa* L. Insecticidal efficacy of developed formulations was tested *in-vitro* against cabbage aphid (*Brevicoryne brassicae* L.) and *in-vivo* against aubergine aphid (*Aphis gossypii* G.) and whitefly (*Bemisia tabaci* G.). EC formulations comprising of seeds extract (40%) were prepared using bio-degradable solvents (50%) and emulsifier blends (10%) with hydrophilic-lypophilic balance (HLB) value (12.54) suitable for the seed oils formulation.

More complicated processes are employed in commercially produced botanical pesticides to yield products of highest quality. Table 4 below displays some commercially produced botanical pesticides as presented by Darka *et al*.(2020).

Active Ingredient	Application	Commercial Product	Company
Oil of neem (Azadirachtin)	Insecticide	Margosom®	Agri Life (Telangana, India)
		AZA-Direct R®	Gowan Company (Arizona, USA)
		Azera TM®	MGK (Minnesota, USA)
		Azamax®	UPL Ltd.a. (Campinas, Brazil)
		Molt-X®	BioWorks Inc. (NY, USA)
		Neemix 4.5®	Certis (Columbia, USA)
		Azatin XL®	OHP Inc. (SC, USA)
		NeemAzal T/S®	Trifolio-M (Lahnau, Germany)
		Fortune Aza 3%EC®	Fortune Biotech (AP, USA)
		Shubhdeep NeemOil®	King AgroFood (Haryana, India)
Essential oil of garlic (*Allium sativum* L.)	Insecticide	AjoNey®	I.H.N. (Mexico)
		EcoA-Z®	EcofloraAgro (Antioquia, Colombia)
		L'EcoMix®	
		CapsiAlil®	
Citrus cinensis L. oil (limonene and linalool)	Insecticide/repellent	Demize EC®	Paragon Professional Pes Control Products (Tennessee, USA)
		Prev-Am®	Oro Agri SA Ltd. (South Africa)
EO of thyme (*Thymus vulgaris*)	Insecticide/repellent	EcoVia WD®	Rockwell Labs Ltd. (North Kansas City, USA)
Rotenone	Insecticide	5% Rotenone ME®	Bejing Kingbo Biotech Ltd. (Beijingm, China)
		Rotenone Dust®	Bionide Products Inc. (NY, USA)
Nicotine (*Nicotiana tabacum* L.)	Insecticide	Nico Dust®	Nico Orgo Manures (Gujarat, India)
		Nico Neem®	
		10% Nicotine AS®	Bejing Kingbo Biotech Ltd. (Beijing, China)
Carvacrol/EO of oregano (*Oreganum vulgare*)	Insecticide/animal feed supplement	By-O-reg+®	By-O-reg+ (SD, USA)

Source: Darka H, Vlatka R and Anita L (2020)

DOSAGE, APPLICATION METHODS, STORAGE,

Botanical pesticides degrade easily within a very limited time and . Hence, it is imperative to apply them as soon as they manufactured / prepared once plants show evidence of pests. Insects are killed either by contact or by ingestion of the insecticides. Some insecticides only repel the insects by a strong odour.

Ahmad *et al*. (2018) evaluated the dose response of neem seed powder against the beetle pest infesting milled products. Surprisingly, better control was observed either at lowest (1% w/w) or the highest doses (5% w/w).

Storage temperature and botanical pesticide formulations have great influence on the efficacy of the pesticide. Lina et al. (2018) used two different plant species to evaluate the safety of mixture formulations of *Tephrosia vogelii* and *Piper aduncum* at various storage temperatures and their insecticidal activity against C. pavonana larvae. Formulations were made from *T. vogelii* and *P. aduncum* (1:5) in emulsifiable concentrate (EC) and wettable powder (WP) form. Both formulations have strong insecticidal activity against C. pavonana. The results showed that LC95 value of EC formulation after storage at condition: below 4°C, room temperature, and 40°C were 0.19%, 0.34% and 0.21% respectively. Based on LC95 value of EC formulation from each treatment, indicated that EC formulation after storage could hold insecticidal activity as good as insecticidal activity before storage due to LC95 value after storage relatively lower than LC95 value before storage (0.35%). In the contrary, WP formulation activity was significantly decreased in all treatments compared to WP formulation activity before storage based on LC95 value.

According to Karani et al. (2017), for field application, the powder can be spread out by hand (broadcasting) over the field crops in a manner similar to fertilizer application or they can be applied at planting time along with the basal fertilizer application and work into the soil or applied around the growing plants by ring method or side banding. Neem dust can be used to control soil borne pests. In the store, the powder is mixed with the product before storage. Under normal circumstances, mode of application and doses for commercial botanical pesticides are described by the manufacturers.

Purkait *et al*. (2019) developed Emulsifiable Concentrate (EC) formulations from seed oils of Pongamia *pinnata* L., *Pachyrhizus erosus* L. and *Annona squamosa* L. Insecticidal efficacy of developed formulations was tested *in-vitro* against cabbage aphid (*Brevicoryne brassicae* L.) and *in-vivo* against aubergine aphid (Aphis gossypii G.) and whitefly (Bemisia tabaci G.). EC formulations comprising of seeds extract (40%) were prepared using bio-degradable solvents (50%) and emulsifier blends (10%) with hydrophilic-lypophilic balance (HLB) value (12.54) suitable for the seed oils formulation. Among nine EC formulations prepared from seed oils of each plant, EC-1 type performed well in terms of emulsion stability, cold test, accelerated storage and flash point test indicating feasibility for their commercial production. *In-vitro* study of *A. squamosa* 40 EC at 1% dose caused the maximum mortality of 80.7% (LC_{50} = 0.08%) against *B. brassicae* at 72 h after the treatment. The bio-efficacy was comparable with the synthetic insecticide dimethoate 30 EC at 0.1% dose. Besides *A. squamosa*, the 40 EC formulation of *P. pinnata* at 1% dose having 70.6% mortality at 72 h after treatment (LC_{50} = 0.19%) was also found promising. *In-vivo* studies in brinjal also indicated the maximum reduction of aphids (67.3–72.3%) and whiteflies (67.5–75.6%) within 5–14 days after application of *A. squamosa* 40 EC formulation at 1.0% dose followed by *P. pinnata* 40 EC. The total flavonoids and phenolic content in all the crude seed extracts varied from 20.9 to 53.9 mg QE/g and 5.8–9.5 mg GAE/g, respectively. Further analysis of the extracts by GC-MS revealed some bioactive constituents belonging to fatty acids, esters, aldehyde, phenols, etc. The study unveiled its significance in developing herbal

insecticidal formulations as an alternative to harmful synthetic chemical insecticides and a step forward towards development of a promising eco-friendly technology in crop protection.

MODE OF ACTION AND EFFICACY OF DIFFERENT BOTANICALS (PLANT EXTRACT).

Grdiša and Grsic (2013) reported that, the most important botanical insecticide is pyrethrin, a secondary metabolite of Dalmatian pyrethrum, neem, followed by insecticides based on the essential oils, rotenone, quassia, ryania and sabadilla. They have various chemical properties and modes of action. However, some general characteristics include fast degradation in sunlight, air and moisture, and selectivity to non-target insects.

According to Dougoud *et al*. (2019), all the selected botanicals contain active ingredients with insecticidal, antifeedant, or repellent properties, and homemade insecticides based on all the selected botanicals have been used with some success to control pests or prevent damage, although efficacy was variable and often lower than the positive controls (synthetic pesticides). Factors affecting the efficacy of homemade botanical insecticide include variation in active ingredient content and concentration in plant material, as well as variation in the preparation process.

Mpumi *et al*. (2016) said that, rotenone from *Thephosia vogelii* delays the electron transport chain in mitochondria of the insects and limits the cellular energy production. Azadirachtin is antifeedant and growth disruptor of insects. Azadirachtin displays strong effects on chemoreceptors of the insects. Pyrethrins are axonic poisons and have repellent effects to insects. It attacks the nervous systems of insects. Sesquiterpene lactones from *Tithonia diversifolia*, Pentacyclic triterpenoids from *Lantana camara, Vernodalin, Vernodalol* and Epivernodalol from *Vernonia amygdalina* have repellent and feeding deterrents chemicals which discourage the insects from feeding the crop. Most active ingredients of botanical pesticides have short life span in the environment.

On the basis of physiological activities on insects, Jacobson (1982) conventionally classified the plant components into 6 groups, namely, repellents, feeding deterrents/antifeedants, toxicants, growth retardants, chemosterilants, and attractants.

Ahmad *et al*. (2018) compared insecticidal efficacy of different plant materials from six commonly grown plants of Pakistan, viz. *Allium sativum* (Alliaceae), Zingiber officinale (Zingiberaceae), *Cymbopogon citratus* (Poaceae), *Eucalyptus globulus* (Myrtaceae), *Nicotiana tabacum* (Solanaceae), and *Azadirachta indica* (Meliaceae) against T.

castaneum infesting stored wheat, rice, corn and gram pulse. Various plant parts were dried, powdered, and used as admixtures to the stored commodities in the experiments. The results have suggested that *A. sativum* (garlic) and *Z. officinale* (ginger) were more effective resulting into 15 times higher adult mortality and 4 to 5 times reduction in grain weight losses when mixed with rice grains. Similarly, *A. indica* when admixture with wheat checked the population growth in the resources resulting into 3.5 times less adult production compared to controls. Better control was observed either at lowest (1% w/w) or the highest doses (5% w/w) of neem seed powder against the beetle pest infesting milled products. The results of this study support the use of botanicals for stored product pest management.

Siazemo *et al*. (2020) reported that neem treatment had the highest maize yield of 4.9 t ha^{-1} followed by Cypermethrin with 4.7 t ha^{-1}, Chinaberry and Garlic with 4.3 t ha^{-1} corresponding to the effectiveness of 67%, 65%, 60% and 60% respectively in relation to the potential yield. It was concluded that the three botanicals' extracts were as effective as cypermethrin as a control measure for the FAW and may be an alternative method for FAW control among small scale farmers in Zambia.

Kumbhar (2020) and Landscape IPM (2023) provide details of some plant species, chemical compounds and their mode of actions as summarized in Table 5 below.

Table 5. Different plant species, chemical compounds and mode of action.

Plant Species	**Pesticidal Substance/Compound**	**Mode of action**
Tanacetum cinerariifolium (Chrysanthemum cinerariifolium)Chrysanthemum cinerariifolium (pyrethrum) Asteraceae family	Pyrethrins obtained from the flowers.	Irritating effect or "knock down" which causes the insect to stop feeding as soon as it encounters a treated surface. It acts both on the central nervous system and in the peripheral nervous system causing repetitive discharges, followed by convulsions.
Azadiractin indica (Neem tree) Meliaceae family	Azadiractin compound is a tetraterpenoid found in bark, leaves and fruits but	Has antifeedant activity, is a growth regulator, inhibits oviposition and a sterilizing compound.

	seeds have the highest concentration.	
Ryania speciosa (Flacourtiaceae).	Ryania obtained from the roots and stems. Obtained a series of alkaloids, of which the most important is ryanodina.	Effective as a contact or stomach poison and directly prevents muscles from contraction, causing paralysis.
Schoenocaulon officinale (Liliaceae).	Sabadilla obtained from seeds which have high concentrations of alkaloids. The isolated alkaloids are both highly toxic and skin irritants.	Disruption of neuron cell membranes causing reduction of nerve activity, paralysis and death
Derris spp. (Fabaceae) and *Lonchocarpus spp*. (Fabaceae).	Rotenone is a flavonoid extracted from the roots	Is a contact and ingestion compound, which acts as a repellent too. Inhibiting insect metabolism, causing a drop in oxygen consumption, respiratory depression and ataxia leading to convulsions and finally to paralysis and death by respiratory arrest.
Nicotiana tabacum (Solanaceae)	Is an alkaloid obtained from some Solanaceae plants. Found in the plant in the form of maleates and citrates.	Causes the production of new nerve impulses which cause convulsions and death.
Source: Kumbhar C. R. (2020) and Landscape IPM. (2023).		

Mpumi *et al*. (2016) provide a list of common active ingredients with generic names that can be found in different plant species and used as botanical pesticides (Table 6).

Table 6. Toxicity of certain botanical pesticides active ingredients (mg/kg).

Generic Name	Oral LD_{50}	Dermal LD_{50}	Signal Word

Pyrethrins	1200 - 1500	>1800	Caution
Rotenone	60 - 1500*	940 - 3000	Caution
Sabadilla	4,000	-	Caution
Ryania	750 - 1200	4000	Caution
Nicotine	50 - 60	50	Danger
d-Limonene	>5000	-	Caution
Linalool	2440 - 3180	3578 - 8374	Caution
Neem	13,000	-	Caution

Source: Mpumi *et al*. (2016)

Rajashekar *et al*. (2012), present a list of insect toxicity and active principle for some plant species as presented in Table 7 below.

Table 7. Insect toxicity and active principle

	INSECT TOXICITY	**ACTIVE PRINCIPLE**
1.	CONTACT	Anonaine, E-Anethole, *β*-Asarone, Z-Asarone, Bornyl acetate, Camphor, (+)-3-Carene, Carvone, Cinnamaldehyde, Dioctyl hexanedioate, Estragole, (+)-Fenchone, Hexa decane, Hexadecanoic acid, Limonene, Nicotine, *β*-Pinene,
2.	CONTACT AND INSECT GROWTH REGULATOR	Azadirachtin,
3.	CONTACT AND FUMIGANT	Carvacrol, 1,8 Cineole, (−)-Limonene,
4.	FUMIGANT	Eugenol, Linalool, *α*-Pinene
5.	CONTACT AND STOMACH POISON	Pyrethrin I and II, Rotenone, Ryania, Sabadilla
6.	STOMACH POISON	Spinosyn A and D

Lengai *et al*. (2020) compiled a list of plant species, mode of action and targeted pest as presented in Table 8 below.

Table 8. Mode of action of selected botanical pesticides on selected crop pests.

Source Plant	Mode of action	Target pests
Neem (*Azadirachta indica*)	Binding to acetylcholine receptors thereby disrupting the nervous system	Insects
	Repellence	
	Feeding deterrence	
	Inhibition of oviposition, egg hatching and moulting	
Garlic (*Allium sativum*)	Delay and inhibit spore germination	Fungi
	Inhibits protein and DNA synthesis	
	Inhibits production of mycotoxins	
	Disrupts cellular components and their activities	
	Hyphal and mycelial modifications	
Aloe vera	Inhibits cellular activities	Bacteria
	Impairs permeability of plasma membrane	
	Denatures proteins	
	Inhibits ATP production and glucose uptake	
Tagetes erecta	Inhibits egg hatching	Nematodes
	Larval toxicity	
	Structural modification	
	Mortality	
Nepeta nuda subsp *nuda*	Host plant manipulation	Viruses
	Inhibits virus replication and multiplication	
	Prevents virus adsorption	
	Inhibits nucleic acids liberation	

Sourc Lengai *et al*. (2020).

El Shafie and Almahy (2012) explained that, a significant mortality of 62.83% resulted from the neem seeds stored in the refrigerator on the 7th day of exposure. The seeds stored in the sun caused a mortality of 48.49%. The water extract from the seeds which were stored at room temperature, resulted in significantly high cumulative larval mortality of 50.30%. The efficacy of neem seeds kept in the sun was negatively affected and correlated with the length of storage period. However, the efficacy of the neem seeds

stored in the refrigerator was increased with storage time. The pupal mortality due to spraying with water extract from neem seeds stored in the sun, refrigerator and room temperature was 49.67, 68.12 and 69.43% respectively. The mortality in the control (water treatment) was 7.33%. The results indicated that grinding of neem seeds before storage seems to have no effects on their efficacy.

While the mode of action remaining the same, the efficacy of the product may be highly influenced due to environmental conditions and the methods of preparation.

CONCLUSION AND RECOMMENDATIONS

- Botanical pesticides are prepared from many different plant species and from different parts of the plants.
- One plant species may have different plant parts with different concentrations of pesticide compounds
- One plant species may have single or more active principle(s) with similar or different mode of action to the insect.
- Botanical pesticides can be in the different forms, eg power, oils, emulsifible solution etc.
- Botanical pesticides are different and therefore their modes of actions are different, hence it is important to know the chemical compounds present in the plant how they affect the insects.
- Methods of application for botanical pesticides will depend on the targeted pests, type / stage of the crop to be treated. Can be applied using sprayers, or by dusting and as admixture for stored and seed products.
- Storage temperature and botanical pesticide formulations have great influence on the efficacy of the pesticide.
- Storage of botanical pesticides in the sun affects negatively the effectiveness of the pesticide
- Generally most botanical pesticides cannot store for long period, and therefore frequent preparation is required.
- While some plant species for preparation of botanical pesticides are cultivated, others are still wild. Effort must be in place to ensure their readily availability and sustainable use of botanical plant species.

ENGAGEMENT STRATEGIES

- Identify right farmers and other appropriate partners to participate in the initiative
- Invite them and create awareness and sensitize farmers, consumers and other stakeholders on the preparation and use of botanical pesticides
- Invite and involve them in a participatory practical training on the identification of relevant plant species and preparation of best botanical pesticides.
- Invite and involve them in initiating and managing crop plot under botanical pesticides use.
- Encourage them to initiate their own plots, prepare and use their own homemade botanical pesticides
- Make a close follow up to provide backup support for the initiative growth.
- Develop them to become promoters of the initiative

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