Journal of Biofertilizers & Biopesticides
ISSN: 2155-6202
Singh, et al. J Biofertil Biopestici 2012, 3:1
DOI: 10.4172/2155-6202.1000114
Review Article
Open Access

Use of Vegetable Oils as Biopesticide in Grain Protection -A Review

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Abstract

Cereals and pulses have great biological and nutritional value in human diet. The losses during growing crops and post harvest handling, processing, storage and distributions systems vary between 20-60%. Three major groups of storage enemies are: fungi, insects and rodents. Many insecticides are available that can be used for protection of stored cereals and pulses. The growing awareness of environment as well as health hazards from synthetic pesticides leads to alternate method. Researchers and users are trying organic pesticides/ bio-pesticides for this grain storage purpose. Out of these products, oils from plant origin are one of them, which have been found to possess insecticidal properties. An advantage is that they are easy to apply. There are also some disadvantages to the use of oil: Oil can have an adverse effect on the germination power of the oil treated seeds.

Keywords: Pests; Insecticides; Vegetable Oils; Biopesticides

Introduction

Cereals and pulses have great biological and nutritional value in human diet. Generally it is agreed that grains stores better and more cheaply than other major food. The losses during post-harvest handling, processing, storage and distributions systems vary between 20-60% [1-4]. Everywhere in the world stored products are attacked by a number of storage enemies. Three major groups of storage enemies are: fungi, insects and rodents. These organisms can damage a considerable part of the stored product. Insects, rodents and microorganisms not only consume and/ or spoil the edible and inedible parts of the stored grain but also lead to post-harvest deterioration causing economic losses due to obvious decay and adverse changes in the odor, taste, appearance and nutritive value [5-7]. In addition, the arthropods transfer bacteria and pathogenic 2 fungi that stick to their bodies or disseminate them via faeces [8,9]. If these losses are minimized, the shortage of foods can probably be reduced. In this context, the improvement of grain storage conditions / systems is the first step in this direction. Hence an integrated approach is required for the control of pests and is essential for maintaining the quality of grains during storage as well as in production [3]. In many cases small improvements in storage methods may lead to much better protection of stored product and thus to less loss. A good storage building is one thing, good safety measures another. According to De Groot [10] however, good storage practices combined with good hygiene, adequate drying and all other safety measures will not always be effective in preventing storage losses. Storage pests may still manage to reach the product and leave a trail of devastation. If this occurs we will have to take other measures to protect our storage product. Although controlling physical, chemical and mechanical factors to a large extent can check the degree of deterioration, spoilage of grains, maximum efforts are required to control the spoilage factors of grains, such as insects and mites, rodents, birds and micro flora. The major insect pests are given in table 1. There are many ways of protecting local storage products. Time-honored methods such as the use of natural materials like plants, minerals, and oil are still very effective. Due to the introduction of chemicals, many traditional storage treatments are often forgotten. These chemicals are classified as Insecticides and Roenticides. Some important insectides and rodenticide are as follows:

Insecticides

1. Malathion
2. Pirimiphos-methyl
3. Bromophos
4. Chlorpyrifos methyl
5. Fenitrothion
6. Methacrifos
7. Bioresmethrin
8. Deltamethrin
9. Permethrin
10. Pyrethrum
11. Methoprene
12. Carbaryl
13. Dichlorvos
14. DDT

Rodenticides

(i) Acute Poisons

1. Arsenious oxide
2. Zinc phosphide
3. Sodium monofluoroacetate
4. Antu (α-Naphthyl Thiourea)

(ii) Chronic Poisons

1. Coumafen
2. Chlorophacinone
3. Bromadiolone

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Received August 30, 2011; **Accepted** October 31, 2011; **Published** January 25, 2012

Citation: Singh A, Khare A, Singh AP (2012) Use of Vegetable Oils as Biopesticide in Grain Protection -A Review. J Biofertil Biopestici 3:114. doi:10.4172/2155-6202.1000114

4. Difenacoum
5. Diphacinone

Insecticides Used For Controlling Storage Pests

As mentioned before, many insecticides are available but only few can be used for protection of stored cereals and pulses. Insecticides which are commonly used discussed further. While describing toxicity, it is mentioned whether the insecticide is toxic for human beings and warm blooded animals or not. Always make sure that the container has a label with instructions for application before purchasing it. Be aware that pesticides can have different trade names. The active ingredients, which are being discussed further, should always be mentioned on the label.

Malathion

Malathion may be mixed with grain as a dust or sprayed on walls or floors. As a dust it is one of the insecticides most widely used to protect stored cereals and pulses. The product to be dusted must be well dried; otherwise malathion breaks down very rapidly. Malathion is not suitable for disinfecting storage structures because it is unstable on concrete surfaces or whitewashed walls. There should be a gap of a period of 12-13 weeks between the malathion treatment on grains and their consumption. In that period malathion breaks down completely without leaving harmful residues. Some disadvantages of malathion are:

1. Malathion is not very effective against the lesser grain borer (*Rhyzopertha dominica*).
2. Some insects like red flour beetle (*T. castaneum*) (Herbst), strains of sawtoothed grain beetle (*Oryzaephilus surinamensis* L.) and mosquitoes have already developed resistance against malathion [11,12]. This means that the insecticide is no longer killing insects.
3. Malathion has a nasty smell.
4. Malathion is only slightly effective against caterpillars (tent caterpillars), moths (bud moths, codling moths, pine shoot moth) and mites.

Pirimiphos-methyl

Pirimiphos-methyl has a low toxicity for humans and warm-blooded animals. Pirimiphos-methyl is sold with various trade names viz. Actellic, Actellifog Silosan, Blex. It remains stable, even on relatively wet grain. It is persistent for several months, which reduce the risk of re-infestation by a second generation insects or new ones from outside. Pirimiphos-methyl is active against beetles, moths and mites. It performs well against species resistant to malathion. Pirimiphos-methyl is available in different formulations: dusts, wettable powders, emulsion concentrates and aerosols.

Bromophos

Bromophos has a relative low toxicity (similar to malathion) for human beings and their domestic animals. The most common trade names of bromophos are: Bromofos, Brofene, Brophene, CELA-1942, ENT-27162, Nexion, Omexan. It is more persistent than malathion on concrete surfaces and therefore it can be used for disinfection of storage buildings. It is also more persistent on warm moist grain. Residues of Bromophos are easily destroyed by heating (cooking or baking) the cereals in food preparation. A disadvantage is that Bromophos acts slowly: the adult insect may lay its eggs before it is killed. Bromophos is available as a dust, (to mix with the stored product), or as an emulsion concentrate (to treat stacks of bags or walls and floors).

Chlorpyrifos methyl

Chlorpyrifos methyl has a relatively low toxicity for human beings and domestic animals. The common names are: Brodan, Detmol UA, Dowco 179, Dursban, Empire, Eradex, Lorsban, Paqeant, Piridane, Scout, and Stipend. It is effective against a wide range of storage pests except against lesser grain borer. Mixing Chlorpyrifos methyl with Bioresmethrin could make a very effective mixture against many species viz. *Sitophilus oryzae* (L.), *Rhyzopertha dominica* (F.) *Tribolium castaneum* (Herbst), and *Oryzaephilus surinamensis* (L.) [13].

Fenitrothion

Fenitrothion is very effective against a wide range of insect pests,

Sl No.	Scientific Name	Common Name	Order	Family
A	**Primary Pests**			
1.	a) *Sitophilus oryzae* (Linn)	Rice Weevil	*Coleopteran*	*Curculionidae*
	b) *S. zeamais* (Mots)	Maize Weevil	*Coleoptera*	*Curculionidae*
	c) *Sitophilus granaries* (Linn)	Granary Weevil	*Coleoptera*	*Curculionidae*
2.	*Rhyzopertha dominica* (Fab)	Lesser grain borer	*Coleoptera*	*Bostrychidae*
3.	*Trogoderma granarium* (Everst)	Khapra	*Coleoptera*	*Dermestidae*
4.	a) *Callosobruchus chinensis* (Linn)			
	b) *Callosobruchus maculates* (Fab)	Pulse beetle	*Coleoptera*	*Bruchidae*
5.	*Sitotroga cerealella* (Olivier)	Frain Moth	*Lepidoptera*	*Gelichidae*
6.	*Corcyra cephalonica* (Stainton)	Rice Moth	*Lepidoptera*	*Pyralidae*
7.	*Plodia interpunctella* (Hubner)	Indian Meal Moth	*Lepidoptera*	*Pyralidae*
8.	*Cadra (Ephestia) cautella* (Walker)	Almond or Fig Moth	*Lepidoptera*	*Phycitidae*
B	**Secondary Pests**			
9.	a) *Tribolium castaneum* (Herbst)	Red Rust Flour Beetle	*Coleoptera*	*Tenebrionidae*
	b) *Tribolium confusum* (Jacq)	Confused Flour Beetle	*Coleoptera*	*Tenebrionidae*
10.	*Latheticus oryzae* (Water house)	Long Headed Flour Beetle	*Coleoptera*	*Tenebrionidae*
11.	*Oryzaephilus surinamensis* (Linn)	Saw toothed grain beetle	*Coleoptera*	*Silvanidae*
12.	a) *Cryptolestes ferrugineus* (Olivier)	Red rust grain beetle	*Coleoptera*	*Cucujidae*
	b) *Cryptolestes pusillus* (Schon)	Flat Grain Beetle	*Coleoptera*	*Cucujidae*

Table 1: Stored grain insect pests.

although it is not fully effective against the lesser grain borer which mainly attack wheat, corn, rice and millet. Both the larvae and adults of lesser grain borer are primary pests. They bore irregularly shaped holes into whole, undamaged kernels and the larvae, immature stages, may develop inside the grain. Larval and adult feeding in and on grain kernels may leave only dust and thin brown shells. Fenitrothion can be used to disinfect storage structures or to protect stored produce. It is more persistent than Malathion. Mixing Bioresmethrin with Fenitrothion could make a very effective mixture against many species. Fenitrothion is far more toxic for human beings and domestic animals than the insecticides described above. But because it hardly penetrates into the grains, most of the residues are removed while dehusking. It is available as dust, emulsion concentrate and wettable powder.

Methacrifos

Similar to Fenitrothion, Methacrifos is far more toxic for vertebrates than the other insecticides described previously. Methacrifos is useful in cases where insects are resistant to malathion (maize weevils, rice weevils, grain weevils and the flour beetles). A special characteristic of Methacrifos is that it penetrates into the grains, thus killing larvae inside the kernels. Methacrifos works very well at lower temperatures. It is available as emulsion concentrate and a 2% dust.

Bioresmethrin

Bioresmethrin, the synonymous d-trans-resmethrin, is a synthetic pyrethroid and it has a very low toxicity for humans and animals. It acts mainly as a contact insecticide but inhalation and ingestion are also lethal for insects. Bioresmethrin deteriorates rapidly when exposed to light. Bioresmethrin is effective against the lesser grain borer, so it is especially useful in situations where the lesser grain borer has developed resistance against insecticides such as Malathion, Pirimiphosmethyl, Fenitrothion and Chlorpyrifos-methyl. In these cases Bioresmethrin can be mixed with these other insecticides to improve efficiency of the application.

Deltamethrin

Deltamethrin, like Bioresmethrin, is a synthetic pyrethroid, and has a very low toxicity for vertebrates. However, the formulation of Deltamethrin in vegetable oil has dangerously high toxicity. Deltamethrin is stable on grain for a long time, but because it does not penetrate the grains, it is removed by dehusking. Deltamethrin is very effective against the lesser grain borer which is not very susceptible to Malathion, Pirimiphos-methyl, Fenitrothion and Chlorpyrifos-methyl. It also is very effective against the grain weevil (*Sitophillus granarius*).

Permethrin

Permethrin also is a synthetic pyrethroid. It has a very low toxicity to human beings and animals (except for fishes). When dissolved in oil its toxicity is much higher however. Permethrin is effective against a large range of insects and especially against the lesser grain borer. It has little effect against flour beetles though. It is very persistent on grain and not very sensitive to moisture. Because Permethrin is effective against the lesser grain borer, it is often mixed with Malathion, Pirimiphos-methyl, Fenitrothion and Chlorpyrifos-methyl, in cases where the lesser grain borer has developed resistance. The efficiency of Permethrin (and other synthetic pyrethroids) is improved by adding Piperonyl -butoxide. Permethrin is especially important also for the control of the larger grain borer (*Prostephanus truncates*), these two grain borers are of the same family, which is very sensitive to synthetic pyrethroids. Permethrin is available as dust (0.5 %). For the protection against the larger Grain Borer it seems more effective to store and treat shelled maize instead of maize (*Zea mays*) on the cob.

Pyrethrum

Pyrethrum show low toxicity to human beings and the domestic animals. It exerts rapid effect on a various insects, but sometimes after treatment insects can recover. To overcome this problem, Pyrethrum is often mixed with some other insecticides, especially Piperonyl-butoxide. The mixture also is cheaper because a lower doses of Pyrethrum can be used (Pyrethrum is expensive). Pyrethrum is available as oil solutions and solution concentrates. Wettable powders and dusts have a short shelf-life.

Methopren

Methoprene is effective against a wide range of storage pests. It has a very low toxicity against human beings and warm-blooded animals. It is effective against the lesser grain borer, but the Grain weevils, Rice weevils and Maize weevils are less sensitive to Methoprene. Methoprene does not directly kill the insects, but it inhibits the reproduction. In this way it prevents development of large populations of insects.

Carbaryl

Carbaryl is not effective against storage pests in general, but it is effective against the lesser grain borer as such. It is used in combination with Malathion, Pirimiphos-methyl, Fenitrothion and Chlorpyrifosmethyl, in cases where the lesser grain borer has developed resistance. Carbaryl should only be used in combination with these insecticides. Care should be taken because Carbaryl is quite toxic.

Dichlorvos

Dichlorvos is geneally available under various trade names viz. DDVP, Dedevap, Nuvan and Vapona. Dichlorvos is highly toxic to human beings and warm-blooded animals. It vaporizes rapidly and the vapor is very effective against insects. However Dichlorvos is not suitable to use as a fumigant, because the vapour is too volatile. Dichlorvos is therefore mainly used to treat the free space in a store or to disinfect infested grain when brought into the store. Because of the high toxicity of Dichlorvos, it is not recommended to use.

Lindane

Lindane is highly toxic to humans and animals due to its persistency. Residues build up in the food chain and have been traced in milk and meat. As such a there is a danger of chronic poisoning that occurs with long term use. Though lindane is still available, we recommend not using it.

DDT

DDT has no direct toxic effect on human beings or animals, but even small quantities of DDT accumulate in the body. Over a longer period of time the accumulated DDT has proven to be toxic to man and animals. Residues have been found in mother milk. Therefore we should never let DDT come into contact with food products or animal feed. Neither should it be used for treating the external surfaces of bags containing food products, nor for treatment of the insides of containers for food products or animal feed or in any situation.

Rodenticides Used for Control of Rats and Mice

Rodenticides are poisons that kill rodents. Because these poisons are meant to kill warm-blooded animals, they are very poisonous to human beings, their children, their domestic animals and to wild animals. Because the rodenticides are used close to the stored product there is a good chance that the produce gets contaminated with the poison. Rodents can poison the food by walking over the poison and after that spreading it over the food. Therefore we strongly advise not to use rodenticides. If there is no other way, use them sparingly and carefully. Another disadvantage of rodenticides is that they cost money and they are not always in stock. Rodenticides should be used only when other means have failed and then only by someone who is familiar with their use and their dangers. Instructions for use should be included with the container. Use of poison, without proper directions, should be avoided.

Types of rodenticides

The rodenticides that are available will vary from area to area. They are sold under different trade names. Basically there are two kinds of poison used for killing rodents: acute poisons and chronic poisons.

Acute poisons: This is a group of poisons that cause a quick death if eaten by the rodents in small quantities. These are single dose poisons. Rodents need to eat only a mouthful of poison to die within half an hour. However acute poisons are extremely poisonous to man and domestic animals. A practical problem is the bait-shyness induced by this type of poison. If the rat finds the taste of the poison suspicious, he will stop eating it and not swallow enough poison to die. The rat will recover and for a long time he will refrain from eating this type of bait or anything that tastes alike. Rodents also learn very quickly; as soon as a member of the species is found dead from poison the others will avoid the poison. Acute poisons are extremely dangerous to man and domestic animals. They must be handled by an experienced person, who is aware of the precautions to be taken to avoid accidents. Normally they must be used outside, never in stores containing foodstuffs. The most common acute poisons are:

1. Arsenious oxide: Approximately 40 milligrams are needed to kill a 200 grams brown rat (Rattus norvegicus).
2. Zinc phosphide: Used in baits to which fats are added to increase its effect. Less than 10 milligrams is needed to kill a 200 grams brown rat.
3. Sodium monofluoroacetate: It is 20 times more toxic than Zinc phosphide.
4. α-Naphthyl Thiourea (Antu): Should only be used against the brown rat.

Chronic poisons: The chronic poisons or slow poisons are used in lower dosages than the acute poisons. They are added to a food for the rat or mice to eat (bait). They must be eaten for a number of days before death occurs. These poisons cause rodents to bleed inside their bodies. The bleeding occurs from old wounds and thin tissues inside the body, and it will not stop. The chronic poisons have no taste and no smell. The rodents do not know they are being poisoned. This is an advantage because they continue to eat the poisoned food. A disadvantage may be that it requires a lot of poison, a lot of bait and a long time to use chronic poisons well. Another disadvantage is the price. Chronic poisons are more expensive than acute poisons. On the other hand they are less dangerous to man (although still highly toxic) and more effective against rats. The most common chronic poisons used are:

1. Coumafen (or Warfarin): This was for a long time the most popular anti-coagulant. Chlorophacinone is now preferred.
2. Chlorophacinone: Acts in smaller doses than the other slow-acting poisons.
3. Bromadiolone: Useful against species that are resistant to coumafen and chlorophacinone.
4. Difenacoum: Effective against rats that are resistant to coumafen.
5. Diphacinone: A bait which is already mixed with a certain rodenticide.

Chronic poisons are also extremely dangerous to man and domestic animals. Because the chronic poisons have to be available for the rodents for a longer period, the danger that children, cats or dog eat them is much bigger.

Oil as an Optional Grain Protectant

The growing awareness of environmental issues as well as health hazards from synthetic pesticides and associated problems of pests' resistance to most of the insecticides, modern concept of insect growth is developed thereby in term controlling their population. Natural chemicals are environmentally safer than classical insecticides. For this reason various researchers and users are trying to use organic pesticides/ biopesticides for this grain storage purpose. During recent years considerable attention has been paid to: exploitation of plant materials in protection of food commodities from insect infestations. Extracts of some plant species viz. *Lantana camara* [14], *Illicium verum* [15], *Tithonia diversifolia* [16] have been reported to possess strong insecticidal activity against different storage insects. Plant derived products namely, azadirachtin from neem (*Azadirachta indica*), pyrethrin from pyrethrum (*Chrysanthemum cinerariaefolium*), carvone from caraway (*Carum carvi*) and allyl isothiocynate from mustard (Brassica nigra) and horseradish(*Armoracia Rusticana*) oil have received global attention due to their pesticidal properties and potential to protect several food commodities [17-20]. Essential oils produced by different plant genera have been reported to be biologically active and are endowed with insecticidal, antimicrobial and bio regulatory properties [19,21-23]. The volatility and biodegradability of flavour compounds of angiosperms will be advantageous if they are developed as pesticide insecticide [24]. There may be least a chance of residual toxicity by treatment of food commodities with volatile substances of higher plant.

Numerous vegetable oils can be used as a protective additive. An advantage is that they are easy to apply. The oils of peanuts (*Arachis hypogea*), coconuts (*Cocos nucifera*), safflower (*arthamus tinctorius*), mustard, castor beans (*Ricinus communis*), cotton seeds (*Gossypium spp*), soybeans (*Glycine max*.), neem, cucurbits (*Cucumis sativus*) and maize (*Zea mays*) etc. have been used successfully. Not all types of oil will be effective. For example sunflower seed oil is not effective in all cases. Use only small amounts of oil (for instance: 2-4 ml per kg threshed beans) and mix the oil and the product thoroughly. This is best done in a big pot or something similar, and portion by portion. After treatment the product can be stored in sacks. Oil can be used preventively as well as curatively.

Protective action

The mechanism by which oil protects the seeds is not completely clear, but it appears that vegetable oils effect egg laying as well as embryo and larvae development on the surface of the seed. Vegetable oils cause the eggs and larvae to die before they can bore into the seed. If the larvae do manage to penetrate into the seed, because it has not been sufficiently coated with oil, then the treatment produces no further effect and the larvae will develop normally. In some cases female insects are able to lay eggs, but the hatching of the larvae is prevented by the oil.

Curative action

Oil may also kill the insect eggs. When the egg is already present at the surface of the seed or inside the seed, the oil coating prevents gaseous exchanges. So the larvae inside the egg or the kernel will die due to lack of oxygen. Some oils such as those derived from neem, karanja (*Pongamia glabra*), undi (*Calophyllum inophyllum*) and kusum (*Schleichera triguga*) also have an insecticidal effect, and a small amount may kill about 90 % of the Cowpea weevil (*Callosobruchus maculatus*). The protective effect may last for upto 3 months. These oils are not harmful to human beings. Oil can be an effective protection or cure against insect damage. It is important to mix the oil very carefully with the grain or beans. If a small piece of the kernel is not coated by the oil, the adult insect can lay its eggs and larvae may enter the kernel.

Protection of legume-pulses by using vegetable oils

Legume and pulses are the excellent source of protein, rich in important vitamins and minerals. Hence make the diet balanced and nutritive. Bruchid/ pulse beetle (*Callosobruchus spp*.) spoil the stored legume to such an extent that a huge portion of total production is gone waste.

Many researchers have tried to protect legumes from pulse beetle. Edible oils show a very good effect against insect-pest infestation. Khalequzzaman et al [25] used seven vegetable oils viz., sunflower (*Heliunthus annus*, L.), mustard, groundnut (*Arachis hypogaea*, L.), sesame (*Sesamum indicum* L.), soybean, olive (*Olea europea*) and oil palm (*Elaeis guineensis*), each were applied at the rates of 5, 7.5, and 10 ml/kg of grain (0.5, 0.75 and 1% v/w concentrations) as grain protectants of pigeonpea (*Cajanus cajan*) against the pulse beetles (*Callosobruchus chinensis* L.). Effects on progeny emergence, loss in grain weight, and germination up to 66 days after treatment were measured. Adult emergence was completely prevented and the minimum grain loss was achieved by groundnut oil at 1% up to 66 days after treatment. Since treatments with groundnut and palm oils at 5 ml/kg showed high acceptability by consumers, it can be recommended for *C. chinensis* control in stored pigeonpea for approximately two months. Bhatnagar et al. [26] also studied the efficacy of vegetable oils against pulse beetle *Callosobruchus maculatus* in cowpea. These workers used groundnut, sesame, soybean, coconut, mustard and neem oil @ 10 ml/ kg grain and reported that neem oil is the most effective against the pulse beetle followed by coconut, soybean and mustard oil. Singh et al. [27] used soybean oil as seed protectant against the infestation on pigeonpea and studied the effectiveness of soybean oil as seed protectant against *Callosobruchus chinensis* Linn. These workers have reported that refined and crude oil, each @ 0.5 ml/100 gm grains, caused 100% adult mortality within one day of their release. In the case of other doses (0.25 and 0.10 ml), only 40-65% mortality was obtained. They have further reported that grain treated with refined and crude oil, each @ 0.5 ml/100gm grain were free from insect damage and without any apparent loss in the grain weight and seed germination.

Sandbox seed (*Hura crepitans* L.) oil was used to observe the insecticidal activity of oil on oviposition, adult emergence, mortality of immature stages and reproductive competitiveness of the cowpea seed beetle, *Callosobruchus maculatus* [28]. Results obtained show that sandbox oil significantly reduced oviposition and adult emergence in both choice and no-choice experiments. Oviposition was reduced by more than 50 % in the lowest oil treatment (i. e., 0.1 % v/w) while adult emergence was totally inhibited at all the oil concentrations except at 0.1 % oil v/w. Sandbox seed oil evoked 100 % ovicidal activity at all the treatment levels while 100 % larvicidal effect was obtained at 0.2 ml, 0.3 ml and 0.4 ml oil per 20 g of cowpea seeds and 100 larvae. Reproductive competitiveness of the oil-treated bruchids reduced with increase in the concentration of the sandbox oil applied. The frequency of the copulation position gained by the males within 30 min reduced from an average of 14.25 times in untreated males to zero at 1.5 % and 2 % oil treatment levels. Similarly, an average mating frequency of 10.50 times was obtained in the untreated females compared with an average of nil at 1.5 % and 2 % sandbox seed oil concentrations. Sandbox seed oil effectively suppressed infestation and population build up by pulse beetles. Cashew nut oil (CNO), Coconut oil (CONO), Udara nut oil (UDNO), and Neem leaf oil in controlling stored black beans weevil (Callosobruchus chinensis) was investigated [29]. The results showed that the number of eggs and exit holes of *C. chinensis* were not significant at 5 % probability level before treatment with the extracts. Then after two months in storage the black beans were treated with the extracts and there was significant reduction of rate of oviposition and number of exit holes. The plots treated with coconut oil extract proved more effective than other oils Cucurbits (Bitter gourd, small bitter gourd, Ridge gourd and Bottle gourd) seed oils are also effective against the pulse beetle (Callosobruchus chinensis). Mishra et al. [30] used solvent extracted vegetable oils of these seeds as grain protectant against pulse beetle. All the vegetable seed oils were found effective and prevented weight loss at the oil application rate of 6-8 ml/ kg of legume- pulse grain after 60 days storage under laboratory conditions. The milling yield and degree of dehusking is improved after oil application. The small bitter gourd seed oil @ 6-8 ml/kg of grain resulted in the improved apparent degree of dehusking from 40% to 72.59%, 59.88% to 92.44%, 63.39% to 87.50% and 57.0% to 79.43% for pigeonpea, chickpea (*Cicer arietinum*), urdbean (*Vigna mungo*) and mungbean (*Vigna radiata*), respectively. Cucurbits have bitter chemicals called cucurbiacins: that are the tetracyclic triterpenes having extensive oxidation capacity. They occur in nature, free as glycosides or in complicated forms of taxomonic significance. Some kind of co-evolutionary relationship between cucurbitacae and beetles has been envisaged through the secondary plant substances such as oxygenated tetracyclic triterpenes [31]. The toxicity of three concentrations (5%, 10% and 20% w/v) and spraying schedules (2, 4 and 6 weekly applications) of an extract from West African black pepper (*Piper guineense*) for managing two major post-flowering pests: Maruca pod borers (MPBs) and pod sucking bugs (PSBs) of cowpea (*Vigna unguiculata*) was investigated [32]. The higher concentrations (10% and 20% w/v) and more frequent applications (4 and 6/week) significantly reduced the numbers of the two insect pests compared to the untreated control. Pod damage was significantly reduced and grain yields consequently increased in treated plots compared with the untreated control.

The repellent effects of ten oils, Domba (*Calophyllum inophyllum* L), Batu (*Solanam indicum* L), leaf oil and bark oil of Cinnamon (*Cinnamomum verum Presl*.), Mustard oil (*Brassica juncea* Cross.), Neem oil, Mee oil (*Maduka longifolia* Koenig.), Castor oil (*Ricinus communis* L.), Cit-ronella oil (*Cymbopogon nardus* L.) and Sesame oil (*Sesamum indicum* L.) were tested for pulse beetle (*Callosobruchus maculatus* L.) in the laboratory conditions [33]. Data were recorded on distribution, ovi-position and adult emergence. Ventilated containers each with five pairs of newly emerged adults with 20 green gram seeds were exposed to different oil vapours at the rate of 200µml. Each container was fixed to a device that provided a tunnel for pulse beetle to escape from or enter into any container. Cit-ronella oil, neem oil, cinnamon leaf oil and cinnamon bark oil vapours resulted in significantly lowest number of pulse beetles after infestation and their oviposition and adult emergence indicating the highest repellent action and toxic effects. Mustard oil, domba oil, mee oil, castor oil and batu oil show indications of higher repellent effect 4DAT (Days after treatment) on the distribution of the *C. maculatus*. Mustard oil and Domba oil showed a lower rate oviposition than that of Mee oil, Castor oil and Batu oil. All the treatments except Sesame oil had significantly reduced adult emergence at 18DAT (Days after treatment). Sesame oil showed positive effect on distribution, oviposition and adult emergence and no repellent activity against the pulse beetle. Essential oil from the leaves of Bael (*Aegle marmelos* Correa) was also found effective against *Callosobruchus chinensis* (L.) (Bruchidae) in stored gram [34]. Stored gram (*Cicer arietinum*) was fumigated with the essential oil at 500 µg/mL (ppm). The essential oil at different doses significantly reduced oviposition and adult emergence of *C. chinensis* in treated cowpea seeds. The oil protected stored gram from C. chinensis. Limonene (88 %) was found to be the major component in the oil through GC-MS (Gas Chromatography-mass spectometry) analysis.

Traditional Indian tree Neem oil as also a good insect-pest protectant. The toxicity of Neem oil against the pulse beetle *Callosobruchus chinensis* Linn. was studied in different pulse grains and persistant toxicity of neem oil was reported to be highest in the green peas followed by cowpea and lowest in the bengalgram [35]. He reported that 100% mortality was observed by neem oil up to 14 days of treatment in green gram and cowpea. Das [36] has reported cent percent mortality within 4 days of released of pulse beetle in chickpea treated with 1% neem oil. Neem seed oil 1% w/w and soft stone 0.5, 1.0 % w/w and neem seed kernel powder 4% w/w have been reported as grain protectant of pigeon pea against the pulse beetle *Callosobruchus chinensis* Linn [37]. They also reported that neem seed kernel powder and neem seed oil protected the grains for a period of 8 months. Bajpai and Sehgal [38] have studied the field efficacy of neem, karanj and tobacco formulations (2.0% neem oil, 2.0% Karanj oil, 40% w/v Nicotine Sulphate) against *Helicoverpa armigera* on chickpea and reported that the treatment of chickpea with neem, karanj and tobacco formulation significantly reduced the pod damage and increase the grain yield over control. Spices are also effective in protecting the legume- pulses according to [39]. They evaluated the effectiveness to control the bruchid, *Callosobruchus maculatus* in cowpea by the synthetic insecticide Actellic dust, and by the natural protectants ash, coconut oil, powdered cloves and black pepper. The data collected included the number of damaged and undamaged seeds, weight of damaged and undamaged seeds and the number of live and dead bruchids. Seeds treated with Actellic dust and black pepper powder had significantly low percentages of damaged seeds. Black pepper powder and coconut oil showed good potential in protecting cowpea against bruchid damage. Microbes (fungi and bacteria) can also be used along with the bioinsecticides for the better results of protection [40]. They used fungi *Beauveria bassiana, Metarhizum anisopliae, Verticillium lecanii and Bacillus thuringiensis*. Cumulative mortality of *B. rufimanus* beetles increased gradually by increasing the period of exposure to foam treated with the different tested oils. In field, *B.bassiana, M. anisopliae*, mustard and nigella oils treatments gave the highest protection to broad bean (*Vicia faba*) against *B. rufimanus* infestation. In the duration of 60 days the infestation percentages did not exceed, 13%, 15 %, 20% and 20%, respectively. The highest percent of seed damages was recorded in the untreated plots. After 5 months, *B.bassiana, M.anissoplia*, mustard and nigella treatments had a significantly lower percent of grain damage and lower seed weight loss (10%, 15%, 17% and 22%), respectively.

Protection of cereal grains by using vegetable oils

To protect cereal grains from infestation, different aforesaid chemicals are being used and the residues of these chemicals may cause harm to humans. So it is necessary to look for a safer way of protecting the grains. Use of Vegetable oil for grain protection is one of the options. Many researchers have worked in this direction. Tembo and Murfitt [41] used vegetable oils (groundnut, rape seed and sunflower) at 10 ml/kg and tested alone and in combination with pirimiphos-methyl at, or of the recommended dosage against *Sitophilus granarius* (L.) in wheat grain (*Triticum aestivum*). All bioassays were conducted at 20 and 30°C. All treatments caused significant mortality compared to controls (untreated grain). Treatments with vegetable oils combined with pirimiphos-methyl at half the recommended dose were as effective as pirimiphos-methyl at the recommended dose for achieving complete control. The same treatments remained effective after 90 days of storage. The vegetable oils alone achieved considerable mortality (60–80%) within 14 days and there was little difference between the three oils in their effect. Pirimiphos-methyl activity was dose dependent. When applied alone, the vegetable oils and pirimiphos-methyl at reduced rates were less effective than combined treatments. The toxicity and persistence of treatments did not vary significantly between 20 and 30°C. Viability and water absorption were reduced by the oil treatments, but particle size distribution after milling was unaffected. Treatment of grain with pesticide/vegetable oil mixtures could have important practical implications for parts of the world where pesticides are expensive or in short supply. Chander et al. [42] have worked on storage of milled rice and reported that the milled rice is prone to various insects and pests which cause extensive qualitative and quantitative deterioration. Due to indiscriminative use of insecticides, there has been an increase in the harmful residues causing general health hazards. These workers have suggested the use of indigenous plant materials as an alternative to chemical controls. These researchers have assessed the effect of different plant materials in the form of grits and powder mixed with milled rice (0.5% conc) and turmeric+ mustard oil (2.5 gm/kg) on the multiplication of the insects. They have reported that as the storage period increases the count of insects decrease with respect to the control. They have further reported that even grits were as effective as powder in suppressing the populations build up of insects.

The insecticidal action of five locally available plants namely: *Azadirachta indica* (Neem), *Cymbopogon citratus* (Lemon Grass), *Lantana camara* (Lantana), *Ocimum basilicum* (Basil) and *Tagetes erecta* (African marigold) against maize weevil, *Sitophilus zeamais* Motsch was investigated by Parugrug and Roxas [43]. Results revealed that all test materials exhibited repellency action against maize weevil. Within 96 hours of exposure powdered leaves of neem and lantana were noted to be highly repellant while powdered leaves of lemon grass, basil and African marigold were observed to be moderately repellant against maize weevil. Corn grains treated with powdered leaves of lemon grass and basil exhibited a low mortality of 5.3% and 0.6%, respectively, at 24 DAII(days after insect introduction). Other test plants revealed zero adult mortality. None among the test plants manifested anti-ovipositional and growth inhibitory action against maize weevil. All examined corn grains except for carbaryl - treated corn grains showed larval tunnel. The total development period of the maize weevils emerged from both treated and untreated corn grains was the same (39 days) and 100% insect survival was noted. The adult body weight was comparable among treatments. Efficacy of Neem oil as grain protectant against *Sitophilus oryzae* and *Tribolium castaneum* was also supported by the investigation carried out by Kumar et al. [44] and Ahmed et al. [45].

Essential oils of plants are also useful in protecting the grains. It is clear from the studies of Rupp et al. [46] He used the extracts of *Piper* *nigrum* and the essential oils of *Ocimum basilicum* and *Eucalyptus globules* in the stored corn grain protection against *S. zeamais*, through the determination of mortality effect on exposed individuals to treated grains. To study the poisonous effect of the extracts on adults of *S. zeamais*, 6 concentrations (50; 25; 12.5; 6.25; 3.125 and 1.5625 %) of each extract were tested, in 40 g of corn containing 20 adults of *S. zeamais* of 0-72 h of age. The experiments consisted of 4 repetitions for each treatment. The same conditions were repeated for the experiments with essential oils of *O. basilicum* and *E. globulus*, where each portion received oil 0.1 mL in 40 g of corn. The evaluations were made to the 1, 3, 5, 7, 10, 15, 20 and 30 days after the treatments of the grains. The insects died were counted in each experiment, being discarded after each evaluation. Significant differences were not observed in the mortality of *S. zeamais* in the different concentrations of *P. nigrum* in relation to the control, indicating the use of insufficient dosages to promote the wanted poisonous effect. As for the essential oils, *E. globulus* stood out promoting adults' mortality, however at low levels of efficiency. The need of new tests of the tested treatments seeking to obtain significant control of the populations of insects in products stored with the use of derived natural products of plants is essential. One more essential oil from leaves of *Aegle marmelos* was tested for the protection purpose of wheat from *Rhyzopertha dominica* (F.) (Bostrychidae), *Sitophilus oryzae* (L.) (Curculionidae) and *Tribolium castaneum* (Tenebrionidae) [34]. The findings emphasize the efficacy of *A. marmelos* oil as fumigant against insect infestations of stored grains and strengthen the possibility of using it as an alternative to synthetic chemicals for preserving stored grains. Various edible vegetable oil are good grain protectants. Dey and Sarup [47] studied the feasibility of protecting maize variety with vegetable oils to save the losses in the storage due to *Sitophillus oryzae* Linn. These workers have reported that out of mustard, soybean, coconut, groundnut, cottonseed, sesame and castor oils, coconut and soybean oils at 3.3 ml/kg grain were found to be highly effective in protecting the grains of various maize varieties. Obeng-Ofori and Reichmuth [48] also used plant oils (coconut, sunflower, sesame and mustard) at 10 and 5 ml/kg alone and in combination with 1,8 cineole, eugenol or camphor at 0.5, 1.0 and 5.0 ml or mg/kg against *Sitophilus granarius* (L.), *S. zeamais* (Mots.), *Tribolium castaneum* (Herbst) and Prostephanus truncatus (Horn) in wheat and maize-treated grains stored for 3 h or 10, 30, 60 and 90 days. All treatments with either plant oils alone or in combination with each chemical caused significant mortality compared with untreated grain. Plant oils when used alone were less effective against the beetles than oils combined with either 1,8 cineole, eugenol or camphor. Mortality significantly decreased with the time after application except in treatments combining plant oils and chemicals, which achieved complete control of all beetles exposed after 90 days storage following application. Treatments with plant oils and each chemical either alone or in combination inhibited progeny production by *S. granarius, S. zeamais* and *P. truncatus*, irrespective of dosage used or of storage interval following application.

Plant oils (cottonseed, soybean, corn, groundnut and palm) at different dosages were evaluated by Obeng-Ofori [49] for their ability to suppress the populations of *Cryptolestes pusillus* and *Rhyzopertha dominica* in maize and sorghum. Exposure of adults of both beetle species to grains treated with 10 ml/kg of the different oils induced 100% mortality within 24 h. A dose of 5 ml/kg of each oil significantly decreased the progeny produced by *R. dominica*. Complete protection was achieved on grains treated with 10 ml/kg. These oils also repelled the adults of both species. Percentage weight loss caused by *R. dominica* in grains treated with 5 ml/kg and 10 ml/kg levels were significantly lower than in untreated grains. Oil treatment did not affect the germination and water absorption by maize and sorghum grains compared with untreated grains. The potential use of plant oils in the management of insect pests in traditional grain storage is discussed. Root extracts of *Decalepis hamiltonii* were tested for insecticidal activity against the stored products pests, Rhyzopertha domonica, *Sitophilus oryzae*, Stigobium pancieum, *Tribolium castaneum* and *Callosobruchus chinensis* [50]. Methanolic extract showed LC 50 value of 0.14 mg/cm^2 for all the test species in a filter paper residual bioassay. The extract was effective as a grain protectant for wheat and green gram. The extract did not affect the germination of the treated grains. Castor, corn and karanj oils were found toxic against *Sitophilus oryzae* and *Rhyzopertha dominica* in stored maize. Karanj oil was most effective against *S. oryzae* with the lowest LD50 and LD95 of 0.0433 and 0.0674μl/cm^2, respectively followed by corn (0.0494 & 0.0978) and castor oil (0.4037 & 0.9080) by Michaelraj and Sharma [51]. The same trend was also observed with *R. dominica* but slightly higher values of LD50 and LD95 than *S. oryzae* except castor. *R. dominica* was more susceptible to castor oil in comparison to *S. oryzae*. Grain treatment produced more than 90% mortality of adults of *S. oryzae* with all the oils at 2.5 ml/kg of grains in both the exposure periods (10 & 20 days) with the maximum of 100% in karanj oil followed by castor and corn oils. Karanj oil was significantly superior over other oils having less number of progeny productions of *Sitophilus oryzae* and *Rhyzopertha dominica* and % damage. In case of *R. dominica*, maximum mortality of 66,6% was recorded in karanj oil at 2.5 ml/kg with the exposure time of 20 days, *S. oryzae* was more susceptible to the vegetable oils than *R. dominica*. Although increased time of exposure of insects to the oils gave higher mortality, it also gave more time to the insects, which were alive, to oviposit and feed. So there was corresponding increase in progeny production and damage. Oils from neem, yellow oleander (*Thevetia peruviana*) seeds, and cotton (*Gossypium hirsutum* L.) seeds and stabilized natural pyrethrum (*Chrysanthemum cinerariaefolium*) blends against adult maize weevils (*Sitophilus zeamais*) were investigated [52]. The results indicated that the natural pyrethrum extract blended with cottonseed oil was the most potent against maize weevils. Components of Citrus oil, alone or in combination, show the fumigant insecticidal action and citrus peel oil can be used as antimicrobial agent, and as an insecticide. Various medicinal plant powders, ash of plant origin and sorbic acid were found helpful in reducing the kernel infestation by [53].

Limitations for the Use of Oils

There are also some limitations to the use of oil: Oil can have an adverse effect on the germination power of the oil treated seeds. Therefore it is recommended that seed which is intended for sowing should not be treated with oil. Oils can also be harmful to human beings [54,55]. Cereals that are intended for food should only be treated with vegetable oils. Locally made oil may go rancid which will then make the product taste unpleasant.

Conclusion

From the above discussion it is clear that the uses of chemicals as grain protectants serve our goal but also harm the human beings as the residues of these chemicals are left even after proper control and washing. These chemical also harm the environment. Therefore, for safety and to protect the grains from infestation, we have to look for some eco-friendly materials. Vegetable oils (edible or inedible) are one of the options. Vegetable oils can be used for the protection of our valuable grains from insect infestation along with various other plant materials such as leaves, dust, powder etc without causing an environmental threat.

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