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Plant products as potential stored-product insect management agents – A mini review

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Abstract: To alleviate insect pest problems in storage, synthetic pesticides are recommended, but their use may create toxicity to non-target organisms, development of pest resistance and residues in treated products. There is a worldwide interest therefore, in the development of alternative strategies, including the use of age-old, traditional botanical insect pest control agents. Tissues of higher plants contain arrays of biochemicals, known as "secondary plant chemicals" (or allelochemics), which are defensive in function. They include alkaloids, steroids, phenolics, saponins, resins, essential oils, various organic acids and other compounds. It is well known that secondary plant metabolites may act as kairomones, allomones, stimulants or deterrents of feeding and oviposition, and as antifeedants, insecticides and insect hormone mimics. Many plant allelochemicals including azadirachtin, nicotine, pyrethrins and rotenoids have been developed as commercial insecticides. Some plant-derived insecticides consist of a mixture of biologically active compounds and hence insects develop resistance slowly. Botanical insecticides can be broad-spectrum in activity, safe to use, unique in the mode of action and easy to process and apply. They tend to be less toxic to higher animals and the environment and can be produced by farmers and small-scale industries.

Key words: Stored-product insect pests, allelochemics, botanical insecticides, biorational pesticides

المنتجات النباتية كعوامل محتملة لإدارة حشرات المنتجات المخزونة

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الملخص: يوصى باستخدام المبيدات المصنعة للتخفيف من مشاكل الآفات الحشرية في المخازن، ولكن استخدامها قد يسبب سمية للكائنات غير المستهدفة وتطوير مقاومة الآفة للمبيدات وتواجد متبقياتها في المنتجات المعاملة. ولهذا بدء الاهتمام بتطوير استراتيجيات مكافحة بديلة، وتشمل استخدام عوامل المكافحة النباتية التقليدية، حيث تحتوي الأنسجة النباتية على مجموعة واسعة من المواد الكيميائية الحيوية تعرف بالمواد الكيميائية النباتية الثانوية (أو البدائل الكيميائية) والتي تعرف بوظيفتها الدفاعية. وتشمل هذه البدائل: المواد القلوية والستيرودية والفينولات ومواد السابونين والمواد الراتينجية والزيوت الأساسية والعديد من الأحماض العضوية وغيرها من المركبات. ومن المعروف أن المواد النباتية الثانوية الناتجة عن عملية الأيض قد تعمل كمواد كيرمونية أو ألومونية أو كمواد حافزة ومانعة للتغذية أو وضع البيض أو كمواد تحاكي هرمونات الحشرات. وتشتمل أغلب البدائل الكيميائية النباتية على مواد مثل الأزاديركتين والنيكوتين والبايرثرين والروتينون، وجميعها قد تم تطويرها كمبيدات حشرية تجارية. وتحتوي بعض المبيدات الحشرية المستنتجة من النبات على خليط من المواد الفعالة الحيوية، وبذلك يمكن أن تتطور مقاومة الآفة لهذه المبيدات بشكل بطيء جداً. وتتميز المبيدات النباتية بنشاطها الواسع ضد الآفات والأمان في استخدامها وطريقة فعلها أو تأثيرها الاستثنائي وسهولة تصنيعها وتطبيقها، وتتميز أيضاً بكونها مواد ذات سمية أقل للحيوانات العليا والبيئة، بالإضافة إلى إمكانية إنتاجها من قبل المزارعين والمختبرات الصناعية على نطاق ضيق.

كلمات مفتاحية: حشرات المنتجات المخزونة، البدائل الكيميائية، المبيدات الحشرية النباتية، المبيدات الحيوية.

Introduction

Conservation of reserve food grain stocks is necessary to ensure a continuous supply at stable prices (Talukder, 2005). Losses due to insect infestation are the most serious problem in grain storage, particularly in the developing countries, where poor sanitation and use of inappropriate storage facilities all encourage insect attack (Talukder et al., 2004; Talukder, 2005). It was estimated that more than 20,000 species of field and storage pests destroy approximately one-third of the world's food production, valued annually at more than $100 billion, among which the highest losses (43% of potential production) occur in developing Asian and African countries (Jacobson, 1982; Ahmed and Grainge, 1986). In the USA and Canada, 20-26% of stored wheat was infested by stored-product pests (White et al., 1985). In India, losses caused by insects accounted for 6.5% of stored grains (Raju, 1984). In tropical countries, grain harvested at high ambient temperatures and delivered into storage loses heat only slowly and hence provides ideal conditions for a rapid build-up of many grain insects (Wallbank and Greening, 1976). The efficient control and removal of stored grain pests from food commodities has long been the goal of entomologists throughout the world. Synthetic pesticides are the major tools for crop protection in developed countries. However, considerable problems may arise from the continued application of these insecticides, including genetic resistance of insect species, toxic residues in the grains, handling hazards, health hazards to operatives and pest resurgence (Chiu, 1989; Rembold, 1989; Schoonhoven, 1982; Sharaby, 1988; Shaaya et al., 1997). These problems lead to rapidly rising application and marketing costs. Continuous and heavy usage of synthetic insecticides results in direct toxicity to non-target organisms such as beneficial parasites, predators and others. Certain chemicals may also be concentrated in food chains. Therefore, it may be worthwhile to seek insecticide supplements of natural origin (Owusu, 2001; Talukder and Miyata, 2002).

The search for more selective and biodegradable insecticides is a promising field within stored-product pest management strategies. The azadirachtin isolated from the neem tree, *Azadirachta indica*, hold particular promise as insecticides of botanical origin. They have no known mammalian toxicity, act at low concentrations and are easily biodegradable (Freedman et al., 1979). Tissues of higher plants contain arrays of biochemicals that are thought to be defensive in function. They include alkaloids, steroids, phenolics, saponins, resins, essential oils, various organic acids and other compounds (Beck and Schoonhoven, 1980; Jacobson, 1990). Because of their metabolic roles in the plant were mainly obscure, they are generally known as "secondary plant chemicals" or "allelochemics" produced as metabolic by-products with possible defense functions. It is well known that secondary plant metabolites may act as kairomones, allomones, stimulants or deterrents of feeding and oviposition, and as antifeedants, insecticides and insect hormone mimics (Nawrot et al., 1986). During last three decades, many plant allelochemicals including nicotine, pyrethrins, azadirachtin and rotenoids have been isolated, characterized and developed as commercial insecticides (Berenbaum, 1989). Some plant-derived insecticides consist of a mixture of biologically active compounds and hence insects are not exposed to the same selection pressure as with conventional insecticides and develop resistance slowly (Chiu, 1989).

Insecticide resistance in stored-product pests

The incidence of insecticide resistance is a growing problem in stored-product protection. Resistance to one or more insecticides has been reported in at least 500 species of insects and mites (Georghiou, 1990). Champ

(1985) reported that resistance to pesticides used to protect grain and other stored foodstuffs is widespread and involves all groups of pesticides and most of the important pests. The development of cross- and multi-resistant strains in many important insect species is a serious concern all over the world (Dyte and Halliday, 1985; Zettler and Cuperus, 1990; Chaudhry, 1997). Insecticide resistance problem in different stored-grain insects were reported from different countries including the Australia, United States, United Kingdom, Germany, India, Pakistan, Philippines, Taiwan, Morocco and others (Dyte and Halliday, 1985; Prickett, 1987; Rassman, 1988; Irshad and Jilani, 1989; Zettler and Cuperus, 1990; Sayaboc et al., 1992; Yao and Lo, 1995; Benhalima et al., 2004). Stored products insect pests were found to be resistant against different insecticides including the cyclodienes, bioresme thrin, carbamates, carbaryl, chlorpyrifo, chlorpyrifos-methyl, cyanophos, cyfluthrin, cyhalothrin, cypermethrin, DDT, deltamethrin, diazinon, dichlorvos, ethylene dibromide, fenitrothion, lindane, malathion, methyl bromide, organophosphates, permethrin, phosphine, phoxim, pirimiphosmethyl, promecarb, propoxur, pyrethrins, temephos and tetrachlorvinphos (DARP, 2003). The resistance of certain stored-product pests to widely used food industry pesticides has reached the highest levels ever recorded in the USA (Fehrenbach, 1991). In another example, malathion resistance in stored product insect-pests was reported from all over the world and currently, there are 122 insect-pest species, which are found as resistant to this insecticide (DARP, 2003). Fumigation is still one of the most effective methods for the prevention of stored product losses from insect-pests, but stored product insects were showing a slow upsurge in fumigation resistance (Donahaye, 2000). Widespread resistance to phosphine has emerged in several species of stored-product insects in many countries, which in some instances may have caused control failures (Chaudhry, 1997). Benhalima et al. (2004) investigated the phosphine resistance status of insect pests in Morocco and found that, with the exception of one population of *S. oryzae*, all samples tested contained phosphine-resistant individuals. The rapid spread of resistant strains through international trade is indicative of a problem likely to occur with other stored-product pests (Dyte, 1970). As for example, White and Watters (1984) reported that malathion-resistant stored grain insects enter Canada primarily through international trade.

Alternative strategies for stored-products pest management

The increasing serious problems of resistance to pesticides and of contamination of biosphere associated with the large-scale use of broad-spectrum synthetic pesticides have directed the need for effective, biodegradable pesticides with greater selectivity. This awareness has created a worldwide interest in the development of alternative strategies, including the discovery of new types of insecticides (Heyde et al., 1994). However, new insecticides will have to meet entirely different standards. They must be pest specific, non-toxic to mammals, biodegradable, less prone to pest resistance, and relatively less expensive (Hermawan et al., 1997). This has led to re-examination of the century-old practices of protecting stored products using plant derivatives, which have been known to resist insect attack (Talukder and Howse, 1995; Ewete et al., 1996). Plant-derived materials are more readily biodegradable, less likely to contaminate the environment and less toxic to mammals. Therefore, today, researchers are seeking new classes of naturally occurring pesticides that might be compatible with newer pest control approaches (Talukder and Howse, 1995; Shaaya et al., 1997; Talukder and Miyata, 2002). Talukder et al. (2004) reported that potential use of bioactive plant materials in storage pest management systems might be economic and environmentally friendly. The manipulation of natural product chemicals, such as insect attractants, repellents, stimulants, antifeedants and arrestants, which are normally encountered by insects, may fulfill the required criteria.

Traditional uses of bio-potential plant products

Since the dawn of human history, they tried to protect their harvest produce against arthropod pests. The Egyptian farmers used to mix the stored grain with fire ashes (Abdel-Gawaad and Khatab, 1985). The ancient Romans used false hellebore (*Veratrum album*) as a rodenticide, and the Chinese are credited with discovering the insecticidal properties of *Derris* species. Pyrethrum was used as an insecticide in Persia and Dalmatia, and tobacco plant preparations have been similarly used for nearly 2 centuries (Ahmed and Grainge, 1986). In many areas of the world, locally available plants are currently in wide use to protect stored products against damage caused by insect infestation (Hassanali and Lwande, 1989). Indo-Pakistani farmers use neem leaves for the control of stored grain pests, while various Nigerian tribes use roots, stems and leaves of plants (Ahmed and Grainge, 1986; Ahmed and Koppel, 1985; Giles, 1964; Girish and Jain, 1974; Jotwani and Sircar, 1965). The farmers of Togo protect harvested cowpeas by adding a mixture of sand and plants or ashes and ground paprika (Zehrer, 1984). In northern Cameroon, cowpeas are traditionally mixed with sieved ash after threshing and the mixture put into a mud granary or a clay jar (Wolfson et al., 1991). In Eastern Africa, the leaves of the wild shrub *Ocimum suave* and the cloves of *Eugenia aromatica* are traditionally used as effective stored grain protectants (Powel, 1989). In Rwanda, farmers store edible beans in a traditional closed structure (imboho) and whole leaves of *Ocimum canum* are usually added to the stored foodstuff to prevent insect damage within these structures (Weaver et al., 1991). Owusu (2001) suggested the natural and cheaper methods for the control of stored-product pests of cereals, with traditionally useful Ghanaian plant materials. In some South Asian countries, food grains such as rice or wheat are traditionally stored mixed with 2% turmeric powder (Saxena et al., 1988; Chatterjee et al., 1980). The use of oils in stored-products pest control is also an ancient measure. Botanical insecticides such as pyrethrum, derris, nicotine, oil of citronella and other plant extracts have been used for centuries (Khalique et al., 1987). Pakistani villagers traditionally protect their stored pulses from insect attack simply by coating them with a thin film of edible oil (Khalique et al., 1988; Khan, 1982). More than 150 species of forest and roadside trees in India produce oilseeds, which have been mainly used for illumination, medicinal purposes and as insecticides from ancient times to early 20th century (Mariappan et al., 1988).

Prospects of bio-potential plant products

Over the past 3 decades, there has been much work on the isolation and identification of a wide array of biologically active natural products that in some way affect the behaviour, development and/or reproduction of pests including insects. Secoy and Smith (1983) recorded 677 different species of plants in 131 families suitable for use in plant control. Grainge et al. (1986) produced a suitable list of 1,600 plant species and Ahmed et al. (1984) reported about 2,000 species. Yang and Tang (1988) reported that in China, different parts or extracts of 276 plant species are used as pesticides. Jacobson (1990) in a survey reported that almost 1,500 plant species from 175 plant families act as insect feeding deterrents. In controlling stored-product insects, Talukder (1995) listed 43 plant species as insect repellents, 21 plants as insect feeding deterrents, 47 plants as insect toxicants, 37 plants as grain protectants, 27 plants as insect reproduction inhibitors and 7 plants as insect growth and development inhibitors.

The increasing attempts to replace synthetic insecticides with less expensive and locally available pest control means have been undertaken especially in the tropics (Jermy, 1990). Pesticidal plants are utilized in two main ways: first, the active compounds are isolated, identified, and chemically synthesized. If feasible, these compounds or their active analogues are synthesized and marketed by the chemical industry. The second approach is suitable for farmers in developing countries and for organic farming. Plant tissues or crude products of the plant, such as aqueous or organic solvent extracts, are used directly. These practices are labour intensive, but are often economically and ecologically sound, and do not require sophisticated technology (Yang and Tang, 1988).

Classification of bio-potential plant products

On the basis of physiological activities on insects, Jacobson (1982) conventionally classified the plant components in to 6 groups, namely repellents, feeding deterrents/ antifeedants, toxicants, growth retardants, chemisterilants, and attractants. However, the bio-potential pant products might also be classified as follows:

Repellents

The repellents are desirable chemicals as they offer protection with minimal impact on the ecosystem, as they drive away the insect-pests from the treated materials by stimulating olfactory or other receptors of insects. According to Dethier et al. (1960) an insect repellent is a chemical stimulus, which causes the insect to make oriented movements away from the source of stimulus. Repellents from plant origins are considered safe in pest control operations as they minimize pesticide residues; ensure safety of the people, food, environment and wildlife (Khan, 1982; Talukder and Howse, 1995; Talukder et al., 2004). The plant extracts, powders and essential oil from different bioactive plants were reported as repellent against different economically important stored product insects (Xie et al., 1995; Tripathi et al., 2000; Owusu, 2001; Khan and Gumbs, 2003; Boeke et al., 2004; Talukder et al., 2004). The essential oil of *Artemisia annua* was found as repellent against *Tribolium castaneum* and *Calloso-bruchus maculatus* (Tripathi et al., 2000). A list of known repellents of plant origin is given in table 1.

Feeding deterrents/Antifeedants

Antifeedants, sometimes referred to as "feeding deterrents", are defined as chemicals that inhibit feeding, although do not kill the insect directly (Munakata, 1977). Saxena et al. (1988) defined antifeedants as chemicals, which retard or disrupt insect feeding by rendering the treated materials unattractive or unpalatable. Antifeedants are of great value in protecting stored commodities from insects. Insects remain on treated food indefinitely and eventually starve to death without eating (Munakata, 1977;

Jermy et al., 1981; Qadri, 1973; Talukder and Howse, 1994; Talukder and Howse, 1995; Talukder et al., 2004). Some naturally occurring antifeedants, which have been characterized, includes glycosides of steroidal alkaloids, aromatic steroids, hydroxylated steroid meliantriol, triterpene hemizectal etc. (Kubo and Nakanishi, 1977; Nawrot et al., 1986; Jacobson, 1990; Klocke and Kubo, 1991; Talukder and Howse, 2000). The screening of several medicinal herbs showed that the root bark of *Dictamnus dasycarpus* possessed significant feeding deterrence against two stored-product insects (Liu et. al., 2002). A list of known feeding deterrent of plant origin is given in table 1.

Toxicants

Toxicants are specific types of chemicals, which directly kill insects. They are also referred as insecticides. Research on new toxicants of plant origin has not declined in recent years despite the increased research devoted to the discovery of synthetic insecticides (Talukder and Howse, 1994; Talukder and Howse, 1995; Xie et al., 1995). Worldwide reports on the toxicity of different plant derivates showed that many plant products are toxic to stored-product insects (Su, 1991; Weaver et al., 1994; Xie et al., 1995; Obeng-Ofori and Reichmuth, 1997; Tripathi et al., 2000; Channoo et al., 2002; Park et al., 2003; Boeke et al., 2004; Talukder et al., 2004; Islam and Talukder, 2005). Talukder (1995) listed the use of 43 plant species expressing toxicant effects of different species of stored-product insects. Pascual and Robledo (1998) carried out screening of plant extracts from 50 different wild plant species of south-eastern Spain for insecticidal activity towards *T. castaneum* and reported that four species namely, *Anabasis hispanica, Senecio lopezii, Bellardia trixago* and *Asphodelus fistulosus* were found as most bioactive plants. Two major constituents of the essential oil of garlic, *Allium sativum*, methyl allyl disulfide and diallyl trisulfide were found as potent contact toxicant, fumigant and feeding deterrent against *Sitophilus zeamais* and *Tribolium castaneum* (Huang et al., 2000). The essential oil vapours distilled from anise, cumin, eucalyptus, oregano and rosemary was also reported as fumigant and caused 100% mortality of the eggs of *Tribolium confusum*, and *Ephestia kuehniella* (Tunc et al., 2000). A list of known toxicants from plant origin, reported as effective on stored-product insect-pest management, is given in Table 1.

Grain protectants

From the very early time, plant materials have been using as a kind of natural protectant to protect the stored-grins. Neem plant parts i.e. leaves, crushed seeds, powdered fruits, oil etc. are most traditional example in this regards (Jotwani and Sircar, 1967; Devi and Mohandas, 1982; Talukder et al., 2004; Islam and Talukder, 2005). Yadave and Bhatnagar (1987) reported that from the very old time, dried leaves of *Azadirachta indica* have been mixed with stored-grains for protection against insects. In parts of Eastern Africa, leaves of some plants have traditionally been mixed as grain protectants (Hassanali et al., 1990). Talukder (1995) listed the use of 43 plant species as grain protectant against stored-product insects. Grain protectant potential of different plant derivatives including the plant oil against major stored-product pests were also found very promising and could reduced the risks associated with the use of insecticides (Obeng-Ofori and Reichmuth, 1997; Shaaya et al., 1997). Worldwide reports showed that when mixed with stored-grains, leaf, bark, seed powder, or oil extracts of plants reduce oviposition rate and suppress adult emergence of stored-product insects, and also reduced seed damage rates (Talukder and Howse, 1994; Onu and Aliyu, 1995; Shaaya et al., 1997; Keita et al., 2001; Tapondjou et al., 2002; Talukder et al., 2004).

Reproduction inhibitors

Ground plant parts, extracts, oils and vapour also suppressed fecundity and fertility of many insects. Many researchers reported that plant parts, oil or extracts mixed with grain reduced insect oviposition, egg hatchability, post-embryonic development and progeny production (Ivbijaro, 1983; Saxena et al., 1986; Saxena and Yadav, 1984; Schmidt et al., 1991). A list of 43 plant species as reproduction inhibitors against stored-product insects was published by Talukder (1995). Reports also indicted that plant derivatives including the essential oils caused mortality of insect eggs (Tunc et al., 2000).

Insect growth and development inhibitors

Plant extracts showed deleterious effects on the growth and development of insects and reduced larval pupal and adult weight significantly, lengthened the larval and pupal periods and reduced pupal recovery and adult eclosion (Khanam et al., 1990). The crude extract also retarded development and caused mortality of larvae, cuticle melanization and high mortality in adults (Jamil et al., 1984). It was reported that grains coated with plant extracts completely inhibited the development of insect like *S. oryzae* (Rajasekaran and Kumaraswami, 1985). Plant derivatives also reduce the survival rates of larvae & pupae, and adult emergence (Tripathi et al., 2000). Development of eggs and immature stages inside grain kernels were also inhibited by plant derivatives (Obeng-Ofori and Reichmuth, 1997).

Conclusion

Research carried out worldwide during last three decades has significantly extended our knowledge on botanical pesticides. Many authors have evaluated the anti-insect properties of plant products on various species of stored-product insect-pests. It is clear from their results that it is possible to develop methods of stored-products protection without or with reduced use of synthetic chemical insecticides. Many plant products can be used in the practical control of stored-product insect infestations. The main advantages of botanical pesticides lie in their relative specificity, leaving parasite and predators to supplement the effects of chemical treatment. Many plant derived natural products active against insects could be produced from locally available raw materials, perhaps in many cases right at the site of usage, so as to be relatively inexpensive.

Table 1. List of plant species reported as sources of repellent, toxicant and feeding deterrents.

Plant Species	Reported as		
	Repellent	Toxicant	Feeding Deterrent
Acacia concinna	SE	-	-
Acorus calamus	-	O, RO	R
Allium sativum	O	P	-
Annona indica	SE	-	-
Annona squamosa	SE	L	-
Aphanamixis polystachya	SE	SC, SE	SE
Apium graveolens	O	-	-
Azadirachta indica	O, P, L, SK	O, SP, LP	P, S, SE, O
Bassia longifolia	-	E	-
Boscia senegalensis	-	L, ZE	-
Brassica juncea	SK	-	-
Brassica napus	SE	-	-
Brassica spp.	-	O	-
Brassica trilifolia	-	O	-
Calophyllum inophyllum	-	O	-
Calotropis procera	S, L	LP	-
curcuma longa	-	P	-
Cardiospermum canescens	SO	-	-
Carpa procera	-	-	LE
Carum carvi	-	FE	-
Chenopodium ambrosioides	O	FE, O	LE
Cleistanthus collinus	-	-	L
Cocculus trilobus	-	-	L
Cocos nucifera	-	O	O
Convolvulus arvensis	-	LE	-
Conya discoridis	-	ZE	-
Coriandrum sativum	SE, O	SE, O	-
Cupressus sp.	O	-	-
Curcuma longa	P, R	-	-
Cymbogon nardus	O	-	-
Datura alba	-	LP	-
Eichhornia crassipes	-	LE	-
Elaeis guinensis	-	O	-
Embelia ribes	-	FE	-
Eruca sativa	O	-	-
Eucalyptus globulus	L	LP, M	-
Eugenia caryophyllata	VO	-	-
Gardinia jasminoides	S, L	-	-
Glycine max	-	O	-
Glycomis pentaphylla	SO	-	-
Helenium aromaticum	-	-	T
Homogyne alpina	-	-	T
Intsia bijuga	O	-	-
Inula macrocephala	-	-	E

Table 1 (continued)

Plant Species	**Reported as**		
	Repellent	**Toxicant**	**Repellent Deterrent**
Jatropha gossypifolia	-	SE	-
Juniperus verginiana	O	O	-
Lantana camera	L	TE	TE
Laurus nobilis	LP	-	-
Lavandula gibsonii	T	-	-
Linum usitatisimum	SK	-	-
Lippia geminata	-	-	L
Luffa acutangula	O	-	-
Lupins albus	-	SE	-
Lupinus termis	-	SE	-
Melia azedarach	S, L	O, E	-
Mentha citrata	-	O	-
Momordica charantia	O	-	-
Ocimum basilicum	O	-	-
Ocimum canum	-	LP	-
Ocimum sanctum	O	-	-
Ocimum suave	LO	-	-
Passiflora foelida	-	-	LE
Pelargonium sp.	O	-	-
Perezia multiflora	-	-	E
Piper nigrum	SE	E	-
Polygonum hydropiper	-	L	-
Polygonum serrulatum	LP	-	-
Pongamia glabra	O	O, E	O
Psidium guajava	-	L, LP	-
Ricinus communis	SK	-	-
Sapindus trifoliatus	SE	SP	-
Saussurea lappa	RE	-	-
Schleicher trijuga	-	O	-
Sesamum orientale	-	O	-
Sesamum indicum	-	O	-
Syzgium aromaticum	-	O	-
Synedrella nodiflora	-	-	LE
Tagetes ereta	O	X, Y	-
Tagetes patula	Z	-	-
Thomandersia hensii	-	-	LE
Trigonella foenumgraecum	L	SE	-
Venedium hirsutum	-	-	E
Vitex negundo	LP	L	L
Xeranthemum cylindraceum	-	-	E

Note: L = leaves, B = bark, F = fruits, S = seeds, O = oil, P = Powder, E = extract, C = coat, M = vapour, R = Rhizome, T = plant, V = clove, X = root, Y = stem, Z = flower, K = cake
(Source: Talukder, 1995)

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