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A review on potential broadleaves weed to control stored product insect of rice grain

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Abstract
This review summarizes the research carried out on broadleaves weed in order to control stored product insect of rice grain. Four main rice stored product insect focused are *Sitophilus oryzae, Tribolium castaneum, Rhyzopertha dominica* and *Oryzaephilus surinamensis*. Broadleaves weeds are the plants that identified having medicinal aspect along with chemical compound or secondary metabolite that can control the storage pest insect. This review also summarizes the mode of action for the insects such as contact toxicity that from feeding and repellent. Research on the extract from the broadleaves is one of the alternatives of biopesticides. Moreover, the research still needs further research in many aspects including bioformulation in order to be commercialized. This paper has reviewed the broadleaves from different families to see the most potential weed that have the effectiveness in controlling rice stored product insects. This review represents the attempt to gather together the information in one place.

Keywords: mode of action; *Oryzaephilus surinamensis; Rhyzopertha dominica; Sitophilus oryzae; Tribolium castaneum*

Introduction

Oryza sativa (Linn.), known as rice is an economically crucial cereal and becomes the foremost basic staple food for partly world's populace and continually grown to 100 countries of the world (Oko *et al*. 2012) [56]. Rice becomes the main food that contains calories and proteins. (Rajendran 2002) [65]. Rice becomes one third of world's population food source and facing a problem during storage. Rice storage has been infested by stored product insects (Nirjara *et al*. 2010) [52]. Storage insect pest are categorized in primary and secondary insect pest. These insects affected storage such as rice, maize and others. *Sitophilus oryzae* L. also commonly known as rice weevil and *Oryzaephilus surinamensis* that known as saw toothed grain beetle, are the example of stored product insect that attack the stored rice grain. Next, according the report from United Nations (UN), *Tribolium castaneum* that commonly known as red flour beetle, also one of the main storage insect pest in rice storage (Sallam 2014) [71]. According to Prakash and Rao 1995 [63] another insect attack that can reduce the rice quality during storage is lesser grain borer, *Rhyzopertha dominica* (F). Stored-product infestation gives the outcome of serious losses in food and feed commodities (Rees 1996) [68]. From the infestation, showing the changes in the composition of the chemicals in stored food, decrement in nutritional values and unsafe compounds contamination and allergens (Rajendran and Parveen 2005) [66]. Three general mode of action by these stored product insects are contact toxicity, repellent and fumigation. Fumigation technique is the method use in warehouse to control the insect pests. Phosphine and methyl bromide are widely been used are already be banned. According to UNEP, 2006 [84] methyl bromide cause ozone depletion and the phosphine shows the resistance to insects. Nguyen *et al*. 2015 reported *Sitophilus oryzae* resistance to phosphine fumigant and Xinyi *et al*. 2017 [87] reported *Tribolium castaneum, Oryzaephilus surinamensis* and *Rhyzopertha dominica* resistant to phosphine.

Weeds are known as undesirable and unwanted plant that grows at open land area (Zimdahl, 2007) [90]. There are several characteristics morphological types of weeds such as broadleaved weeds, grasses, sedges, and ferns (Barnes and Chan 1990) [15]. Some weeds are known as medicinal plants that have allelochemicals which made up of secondary metabolites. Secondary metabolites compound that can be found in weeds are alkaloids, sesquiterpenes, monoterpenes, and alpha-pinenes (Badmus and Afolayan 2012) [13]. According to Ahmad *et al.* 2017 [6] bioactive compounds that have insecticidal properties in the weeds are steroids, alkaloids, tannins, flavonoids, phenols, terpenes, and resins. Weeds from family such as Asteraceae, Cladophoraceae, Lamiaceae, Meliaceae, Oocystaceae, and Rutaceae have insecticidal activity (Sukumar *et al*. 1991) [80]. Other plant families that also have insecticidal activity are from Meliaceae, Asteraceae, Rutaceae, Labiateae, Verbenaceae, Piperaceae, and Annonaceae (Isman 1995) [31]. These plant products from weeds have large spectrum activity such as insecticide, anti-feedents, repellents, and insect growth regulators (Guleria and Tiku 2009) [27]. According to El-Kamali 2009 [23] the phytochemicals compound shows the antifeedants, repellents, growth inhibitors or insecticides.

Stored-Product Insects

Stored product pests made up of primary and secondary pests which usually primary for internally and secondary for externally feeding for storage product. As the primary pests are difficult to detect, farmers are the most concern about the situation (Alves *et al*. 2012) [8]. According to USDA in 2016 as a result of insect infestation, about 20-30% losses in food production and stored products are being reported. The damage made by insects such as sucking, chewing or boring into the stored products by directly feed, destroy grains and quicken the decay process (De Geyter *et al*. 2007) [22].

Table 1: Stored-Product Insects

Common name	Family	Species
Rice weevil	Coleoptera: Curculionidae	*Sitophilus oryzae*
Red flour beetle	Coleoptera: Tenebrionidae	*Tribolium castaneum*
Lesser grain borer	Coleoptera: Bostrychidae	*Rhyzopertha dominica*
Sawtoothed grain beetle	Coleoptera	*Oryzaephilus surinamensis*

Nowadays, people are concerning of human health and environment due to the synthetic pesticides that have been used that give harmful and bad effect. Farmers with the help of researchers try to find alternative in order for not using synthetic pesticides in order to control rice product insect. They come out the ways by using plant extract. The utilize plant extracts as alternative becomes the world-wide interest to replace the synthetic chemicals. Numerous plant extracts will be utilized as they wealthy of bioactive chemicals that can be protection of stored product pests (Kim *et al*. 2003) [35]. The extract from plants is known as botanical pesticides. Plant extracts that derived from different families can be utilized as botanical pesticides (Mizubuti *et al*. 2007) [45]. Plant parts that can be utilized to create botanical pesticides are from the bark, roots, leaves, fruits, flowers, seeds, cloves, stems and rhizomes. The guidance in choosing the plant part is the target bioactive compounds that have the insecticidal activity. The plant parts that are collected will be dried and ground into a fine powder. Then, the powder will be extracted with organic solvents that will maximize the extraction towards the focused compounds (Chougule and Andoji 2016) [17]. The extracts are then concentrated, formulated and assessed for adequacy beneath research facility, controlled or field conditions (Zarubova *et al*. 2014) [89]. Botanical pesticides develop resistance with natural interaction between the pests' biochemical (Gaikwad et. al. 2012) [25]. Variety modes of action from the botanical pesticides on the target pests such as repellence, toxicity, growth regulation, and structural modification show great choices in pest management (Kushram et. al. 2016) [36]. The mode of action will interfere with insect behavior, biochemical processes, physiological activities, morphology, and metabolic pathways. Common bioactive compounds that dominant in secondary metabolites of botanical pesticides such as steroids, tannins, alkaloids, flavonoids, terpenes, phenols, and resins that have antifungal, antibacterial, antioxidant, or insecticidal properties (Ahmad et. al. 2017) [6].

Broadleaves Weeds

Broadleaves weeds are chosen in order to control rice grain stored product.

Table 2: Broadleaves Weeds

Bil	Common name	Scientific name	Family
1	Cinderella weed	*Synedrela nodiflora*	Asteraceae
2	Siam weed, Devil weed, French weed and Akintola Taku	*Chromolaena odorata*	Asteraceae
3	Billy goat weed	*Ageratum conyzoides*	Asteraceae
4	Senduduk	*Melastoma malabatrichum*	Melastomaceae
5	Asian spider flower	*Cleome viscosa*	Capparacae
6	Ghamra	*Tridax procumbens*	Compositae
7	Cat's hair, asthma weed and milk weed	*Euphorbia hirta*	Euphorbiaceae
8	Bitter leaf	*Vernonia amygdalina*	Asteraceae
9	Bonomula or Shealmoti	*Blumea lacera*	Asteraceae
10	Wilayati tulsi	*Hyptis suaveolens*	Lamiaceae
11	English black beni-seed, black sesame	*Hyptis spicigera*	Lamiaceae
12	Ram tulsi and Nimmatulasi, Ahuji	*Ocimum gratissimum*	Leguminoceae
13	Amaltash	*Cassia fistula*	Caeselpinaceae
14	Kureel'	*Capparis decidua*	Capparidaceae
15	African spider plant	*Cleome gynandra*	Capparidaceae
16	Spider flower	*Cleome chelidonii*	Capparaceae
17	Lantana, Wild Saga, Bara Phulnoo	*Lantana camara*	Verbenaceae
18	Cholai	*Amaranthus viridis*	Amaranthaceae
19	Giant witchweed	*Striga hermonthica*	Orobanchaceae
20	Sensitive plant/touch-me-not	*Mimosa pudica*	Mimosaceae
21	*Eupatorium inulifolium*	*Austroeupatorium inulifolium*	Asteraceae
22	*Eupatorium viscidum*	*Eupatorium viscidum*	Asteraceae
23	*Eucalyptus dundasii*	*Eucalyptus dundasii*	Myrtaceae

Chemical Compound of Broadleaf Weeds

Plants have secondary metabolites that developed numerous ways to battle against insects. Plant-derived compounds can be a useful source for sustainable and healthy agriculture (Silva *et al*. 2012) [47]. These are weeds families that have chemical compound that have potential for insecticidal activity.

Table 3: Chemical Compound of Broadleaves Weeds

Bil	Weed	Compounds	Reference
1.	*Ageratum conyzoides*	Alkaloids Flavonoids Tannins Saponins Terpenoids Anthraquinones	Agbafor *et al*. 2015 [4]
2.	*Lantana camara*	Alkaloids Phenolic Flavonoids Tannin Saponin	Naz and Bano 2013 [49]
3.	*Chromolaena odorata*	Alkaloids Saponins Tanins Anthraquinones Steroids Tepenoids Flavanoids	Vijayaraghavan *et al*. 2018 [86]
4.	*Blumea lacera*	Flavonoids Alkaloids Terpenoids Steroids	Ahmed *et al*. 2014 [7]
5.	*Cleome viscosa*	Alkaloids Flavanoids Saponins Tannins Steroids	Mali 2010 [41]
6.	*Euphorbia hirta*	Saponins Flavonoids Tannins Steroids	Chukwudi and Yusha'u 2016 [18]
7.	*Tridax procumbens*	Flavonoids Tannins Steroids Phenols Terpenoids Alkaloids	Savithramma *et al*. 2011 [72]
8.	*Vernonia amygdalina*	Alkaloids Flavonoids Saponins Tannins Terpenoids	Adeniyi *et al*. 2010 [3]
9.	*Hyptis suaveolens*	Alkaloids Flavonoids Phenols Saponins Terpenes	Sharma *et al*. 2013 [75]
10.	*Ocimum gratissimum*	Phenols Tannins Flavononols Alkaloids Terpenes	Matias *et al*. 2011 [42]
11.	*Hyptis spicigera*	Alkaloids Flavonoids Saponins Steroids Tannins Terpenoids	Baba *et al*. 2012 [11]
12.	*Cassia fistula*	Flavonoids Phenols Tannins Saponins Alkaloids	Seasotiya *et al*. 2014 [73]
13.	*Capparis decidua*	Alkaloids Terpenoids	Soda 2010 [77]
14.	*Cleome gynandra*	Flavonoids	Neugart *et al*. 2017 [50]
		Phenols	Osama and Awdelkarim 2015 [59]

		Tannins Flavonoids Alkaloids Triterpenes Diterpenes Steroids Saponins	
15.	*Cleome chelidonii*	Alkaloids Tannins Flavonoids Phenols	Nobori *et al*. 1994 [53]
16.	*Amaranthus viridis*	Tannins Flavonoids	Iqbal *et al*. 2012 [30]
17.	*Synedrela nodiflora*	Alkaloids Flavonoids Triterpenes Saponins Simple phenolics	Bhogaonkar *et al*. 2011 [16]
18.	*Striga hermonthica*	Alkaloids Anthraquinones Saponins Steroids Tannins Terpenoids	Baba *et al*. 2012 [11]
19.	*Mimosa pudica*	Alkaloids Flavonoids Tannins	Baby Joseph *et al*. 2013 [12]
20.	*Melastoma malabathricum*	Tannins Alkaloids Steroids Phenol Terpenoid Flavonoids	Danladi *et al*. 2015 [21]

Saponin

Saponins are compounds from steroidal or triterpenoid class that can be found in plants with a diverse range of bioactivities (Podolak, *et al*. 2010) [62]. Saponins recognized beneath non-volatile compounds that have antimicrobial, insecticidal, antioxidant, nematicidal and molluscicidal activities (D'Addabbo *et al*. 2011) [20]. They have been utilized in stored grains to minimize harm to food grain and minimize the loss due to insect pests (Stevenson *et al*. 2009) [79]. Applebaum *et al*. 1969 [9] were first to report the protective part of saponins synthesized against insect attack. Many researchers have tested insecticidal activities of these compounds against important insect pests (Golawska *et al*. 2014). Saponins can be found in wild and cultivated plant species Moses *et al*. 2014 [48] and also in different plants parts like leaves, bark, stems, roots, and even flowers (Moghimipour and Handali 2015) [46]. Saponins specifically influence the development and reproduction of insect pests due to their repellent or deterrent activity. The mortality levels rise up due to the toxicity (Adel *et al*., 2000) [2]. Saponins also functioning that can break the inside lining of mucosal cells within the insects gut (Taylor *et al*. 2004) [81]. Numerous insects refuse to eat saponin that contain in the food as they can die within a few days. Saponins present good demonstrate of study to control insect pests due to their huge range of activities and negative impact on the insects. Many researchers have proved saponins that derived from plant are able to be use and apply against vital insect pests like aphids, weevils, beetles, worms, leafhoppers, and moths.

Flavonoid

Flavonoids are a fundamental class of secondary metabolites which contain about 5-10% secondary products in plants extending from bryophytes to angiosperms. There are approximately 5000 flavonoids reported in plants and continue to increase (Madhuri and Reddy 1999) [40]. Flavonoids have a key role in in plants especially stress response components. The adaptive roles of flavonoids in plant defense are also against insects as they act as antioxidants (McClure, 1986) [44]. Flavonoids such as flavonols, flavones, proanthocyanidins, flavanones, flavan 3-ols, flavans, and isoflavonoids are well-known feeding deterrents against numerous pests (Treutter, 2006) [82].

Tannins

Tannins functioning where it will bind to the proteins, lessening the effectiveness to retain nutrients and by causing midgut lesions that will affect insect growth and development (Sharma *et al*. 2009) [74]. Tannins are effective feeding deterrents to numerous insect pests (Barbehenn and Peter 2011). Digestibility of proteins is reducing when ingested with tannins, therefore diminishing the nutritive value of plant parts. They are principal feeding deterrents against a few insect species (Peters and Constabel 2002) [61].

Alkaloids

Alkaloids can be found in approximately 20% in vascular plant species and characterized in huge family of nitrogen-containing secondary metabolites. Most of them are harmful and serve primarily in defense against microbial infection and herbivore attack (Harborne 1988) [32].

Modes of Action Towards Stored Product Insects

Table 4: Modes of Action towards Stored Product Insects

Bil	Weed	Insects	Mode of action	Reference
1.	*Ageratum conyzoides*	*Tribolium castaneum*	Contact Toxicity/ Feeding	EL-Kamali 2009 [23]
		Sitophilus oryzae	Repellent	Onunkun 2013 [58]
		Rhyzopertha dominica	Contact Toxicity/ Feeding	Moreira *et al*. 2007 [47]
		Oryzaephilus surinamensis	Contact Toxicity/ Feeding	Moreira *et al*. 2007 [47]
2.	*Chromolaena odorata*	*Tribolium castaneum*	Repellent	Onunkun 2013 [58]
		Sitophilus oryzae	Contact Toxicity/ Feeding	Acero 2014 [1]
3.	*Blumea lacera*	*Rhyzopertha dominica*	Contact Toxicity/ Feeding	Ahad *et al*. 2016 [5]
4.	*Cleome viscosa*	*Tribolium castaneum*	Repellent Contact Toxicity/ Feeding	Rimi *et al*. 2017 [70]
		Sitophilus oryzae	Contact Toxicity/ Feeding	Somboon and Pimsamarn 2006 [78]
5.	*Tridax procumbens*	*Tribolium castaneum*	Repellent	Onunkun 2013 [58]
6.	*Vernonia amygdalina*	*Tribolium castaneum*	Repellent	Onunkun 2013 [58]
		Sitophilus oryzae	Contact Toxicity/ Feeding	Law-Ogbomo and Enobakhare 2007 [39]
7.	*Austroeupatorium inulifolium*	*Tribolium castaneum*	Contact Toxicity/ Feeding	Lancelle and Giordano 2017 [37]
8.	*Eupatorium viscidum*	*Tribolium castaneum*	Contact Toxicity/ Feeding	Lancelle and Giordano 2017 [38]
9.	*Hyptis suaveolens*	*Tribolium castaneum*	Repellent Contact Toxicity/ Feeding	Hasan *et al*. 2018 [29]
		Rhyzopertha dominica	Repellent	Tripathi and Upadhyay 2009 [83]
		Sitophilus oryzae	Repellent	Tripathi and Upadhyay 2009[83]
			Contact Toxicity/ Feeding	Olotuah 2011 [57]
10.	*Ocimum gratissimum*	*Sitophilus oryzae*	Contact Toxicity/ Feeding	Law-Ogbomo and Enobakhare 2007 [39]
11.	*Cleome gynandra*	*Sitophilus oryzae*	Contact Toxicity/ Feeding	Somboon and Pimsamarn 2006 [78]
12.	*Cleome chelidonii*	*Sitophilus oryzae*	Contact Toxicity/ Feeding	Somboon and Pimsamarn 2006 [78]
13.	*Synedrela nodiflora*	*Sitophilus oryzae*	Contact Toxicity/ Feeding	Haque *et al*. 2012 [28]
14.	*Mimosa pudica*	*Rhyzopertha dominica*	Contact Toxicity/ Feeding	Ahad *et al*. 2016 [5]
15.	*Eucalyptus dundasii*	*Rhyzopertha dominica* *Oryzaephilus surinamensis*	Fumigant toxicity Repellency	Aref *et al*. 2015 [10]

Discussion

The plant extracts derived chemicals that have potential as insecticides and antifeedants (Pavela 2007) [60]. Plant powder and the extraction of certain family show the best effect on the storage pest insects as they have insecticidal activity. It is due to the toxicity and inhibition of reproduction. Primary and secondary metabolites from plants have can act as insecticidal agents against insect pests (Raliya *et al*. 2018) [67]. According to the table, monoterpene from Austroeupotorium shows antifeedant when tested with *Tribolium castaneum*. Flavonoid from *Ageratum conyzoides* shows antifeedant towards insects. Saponin from *Chromolaena odorata* shows the mode of action antifeeding. Terpenoid from *Ocimum gratissimum* and *Vernonia amygdalina* shows antifeedant towards insect. Fumigation is one of the modes of action. Bio fumigants from the plant origin show selectivity to insect species and easily biodegradable. Therefore, it considered to be the best source of newer chemicals for the development of new, ecofriendly, and safer insect control agents (Khater, 2012) [34].

Some researcher has reported based on their research of plant extract in controlling stored insect pests. As example, *Chromolaena odorata* commonly known as Siam weed is a toxic plant that showing highly toxic to rice weevil. Progeny production by rice weevil completely inhibited due to the high dose of the leaf extract. Phytochemical screening has confirmed the presence of saponins in Siam weed leaf extracts (Obeng-Ofori and Akuamoah 2000) [54]. Next, Rajashekar *et al*. 2012 reported that lab work has shown that leaves of *Lantana camara* are the source of insecticidal activity and preliminary studies indicated that the leaves of *Lantana camara* possessed rich source of bioactive molecules (Khan *et al*. 2002) [29]. The leaves of *Lantana camara* seem to be a promising choice as a source of a new biopesticide. Essential oils and constituents that has been demonstrated and obtained from Lantana camara, and Ocimum americanum were effective repellents against *Sitophilus oryzae, Tribolium castaneum* and *Rhyzoperta dominica* (Regnault-Roger *et al*. 2012) [69]. Insecticidal activity against several crop pests has been shown by *Ageratum conyzoides* towards rice weevils, *Sitophilus oryzae* (Fagoonee and Umrit 1981) [24]. The essential oils from *Eupatorium inulaefolium* Kunth, and *Eupatorium viscidum* Hook. & Arn studied have previously been described as being toxic against *Tribolium castaneum* (Lancelle *et al*. 2009) [38].

Repellents against *Sitophilus oryzae, Tribolium castaneum* and *Rhyzoperta dominica* shows effectively by extraction of essential from *Lantana camara* and *Ocimum americanum* (Ogendo *et al*. 2008) [55]. In controlling stored insects, essential oil-based insecticides are very crucial as they are active against a variety of insects, fast penetrating and no toxic residues in the treated products (Mbata and Payton 2013) [43]. As for *Eupatorium odoratum* or *Chromolaena odorata* shows the potential of antifeedant and insecticidal activities for *Tribolium castaneum* (Yankanchi and Gonugade 2009) [88]. As the chemical compound from the weeds produce triterpenes, it affected the pest insects by mode of action of growth regulation and antifeedant activity (Connolly, 1983) [19].

As we can see from the table, there are four main compound/ secondary metabolites from the weeds such as alkaloids, flavonoids, tannins and saponins. Different weeds shows different mode of action towards the stored pest. The most mode of action is contact toxicity which is feeding and another one is repellent. From the previous study, *Tribolium castaneum* reported more on contact toxicity than other mode of action. *Sitophilus oryzae* also been reported to have more result on contact toxicity. *Rhyzopertha dominica* and *Oryzaephilus surinamensis* reported to have mode of action of fumigant toxicity.

Conclusion

From the experiments done by the researchers, the phytochemical screenings from the broadleaves weeds shows the several chemical compounds/ secondary metabolites in that plant having insecticidal activity. The insecticidal activity can be proved when tested on the rice grain storage pests. The results show some of the insects are Control by contact toxicity which is feeding and some by repellent. So, the use of plant extracts that derived from the broadleaves weeds can be the botanical pesticides in order to replace the synthetic pesticides that have harmful and bad effect to humans, and the entire ecosystem due to high toxicity. On the other hand, plant- based products are cheap and bio-degradable and also environmentally friendly. From the review, we can discover that not many researchers try to do the plant extracts in fumigation form and tested on rice stored products, so this can be the indicator to the researchers to focus in this area.

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