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Insecticidal activity of different plant extract against cowpea weevils (*Callosobrochus maculatus*): A review

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Abstract
The cowpea weevil, *Callosobruchus maculatus* is one of the most prevalent and a major destructive insect pest of stored legumes. Organophosphorus, pyrethroid insecticides, and the fumigants (i.e. phosphine and methyl bromide) are basically use in the control of these insect populations around the world. Although effective, their repeated use for decades has fostered environmental imbalance, sabotaging non-target organisms and human health concerns, high persistence as well as genetic resistance. This present article is a collection of up to date information on biological control of 60 different types of plants extract against the *Callosobruchus maculatus* activity on cowpea and their effect on human health by different authors.

Keywords: *Callosobruchus maculatus,* cowpea, toxicity, oviposition, insecticidal-activity

Introduction
Protection of agricultural stored products against insect pests has proven to be of utmost importance all over the world so as to achieve continuous and safe food supply. [1]. Plant extracts contain biologically active compounds and hence has been the matter of interest for nearly sixty years ago [2]. The phytochemicals are the major subject of interest due to the fact that their large-scale synthesis and production for commercial use is immature. This commercialization can only be achieved when immense knowledge of the phytochemical components and their effect on the stored product as well as human health is acquired.
Cowpea, (*Vigna unguiculata*), is an abundant tropical and subtropical edible legume crop [3]. Due to its high protein content, it is used as an important human food in several part of the world [4] and also used as silage and hay for livestock feed. It is well adapted to drought and short warm weather which serves as an advantage for better yield across different environments [5]. Cowpea grain production is damaged by insects in most cowpea producing nations, which lead to economic losses [6].
Cowpea weevils is found as the most abundant bruchid that attacks and damage unpreserved cowpea. Cowpea weevils **(***C. maculatus*) is a cosmopolitan post-harvest pest of cowpea in the tropics. It infest cowpea on field as well as on storage, rendering it unsuitable for consumption and as they reproduce, great losses can be recorded [2]. The control of these pest is achieved by mostly the used of pesticides for pest control despite the fact that small scale farmers find it difficult to acquire due to financial or technical reasons [5]. These pesticides has also recorded negative effect on non-target animals especially on the field, other crops, environment, and humans [7]. Therefore, the development of alternating, easy, safe and cheap control methods are needed for protecting stored cowpeas against *Callosobruchus maculatus*. In developing an effective less toxic and environmentally friendly method, attention is directed toward the use of natural products usually phytochemicals of plants and their products in the control of food pests. Most bioinsecticide researches were carried out on three biological responses; ovipositional, feeding deterrent as well as contact and fumigant toxicity effect. Actual conditions of cowpea storage are not taking into condition by most authors in laboratory bioassay. Long-term storage condition that are close to possibly to on farm storage should be considered in a controlled laboratory environment. In this review, we present a range of several phytochemicals (mostly essential oils and alkaloids) of important plants and their toxic effects on several control measures of cowpea weevils. We also present some active

compounds and their effect on stored grain as well as suitability for human health with respect to the toxicity effect of the concentration of each extract used by various authors.

Fumigant and Contact Toxicity Effect

Fumigant and contact toxicity are methods that uses substances in gaseous form to eradicate pests, as an approach that can be used in the control of agricultural stored products. The use of plants phytochemical extracts by fumigant and contact toxicity method, demonstrated the reason for the higher efficacy of this method [8]. Certainly, this method exhibit several obvious advantages in terms of ability to keep an effective concentration of insecticides within the closed space, easiness of use, volatility of essential oils and a high possibility to spread the substance consistently, considering even hard-to-reach places [6].

An aqueous and the ethanoic extracts of *E. caryophyllus, B. pinnatum, E. camaldulensis,* and *X. aethiopica* induced insect mortality of 71.21 ± 0.25%, 81.42 ± 0.25%, 80.00 ± 0.23%, 100.00 ± 0.00% respectively at 5 ml doses of aqueous plant [9]. Bioassay was done by a direct contact application of ethanol extracts of *A. sativum L.* (Garlic), *C. millenii* Baker (Manjack), *M. myristica* (Gaertn.) (Nutmeg), *X. aethiopica* (Dunal) (Negropepper) and *Z. officinale* Roscoe (Ginger) using three concentrations (50, 75 and 100mg/ml) of each extract in 10g of previously disinfested cowpea seeds containing 10 adults of *C. maculatus* of 1-2 days old. The results revealed that all the plant species shows lethal effects on the insect as compared with the untreated check (See Table 1) [10]. A fumigation bioassay without grain was carried out on 10 adult *Callosobruchus maculatus* exposed to essential oils of *M. alternifolia*, *C. zeylanicum*, *S. aromaticum*, *C. flexuosus*, *T. vulgaris*, E. *globulus*, *S. chinensis*. It was found the increasing concentration of different oils and exposure period is directly proportional to percentage mortality increased [1]. A water extracts of *C. retusa, H. suaveolens, R. commonis* and *T. diversifolia* demonstrated that the aqueous extracts has efficient lethal effect and considerably reduced oviposition. *T. diversifolia* was found to show the highest effect on cowpea weevil, then extract from *C. retusa*, *R. communis* and *H. suaveolens* has the least potent extracts [11]. A laboratory experiment also shows that mortality rate of cowpea weevils decreases as the weeks after the application of treatments increases. At fourteen weeks the mortality was highest for *A. indica* followed by Aleo vera, Trema, flame seed [2]. *C. colocynthis, T. orientalis, N. physaloides, D. viscosa, S. terebinthifolius, C. lanceolatus* and *C. longa* were extracted consecutively with petroleum ether, chloroform and ethyl alcohol. Petroleum ether extracts of *C. colocynthis* proved to be the least effective, while petroleum ether and chloroform extracts of *N. physaloides* proved to be the most toxic in comparison to other tested extracts [12].

Ethanolic extracts of Balsam spurge and Henna tree leaf were tested by exposing five pairs of adult weevils to 20 g of cowpea mixed with various conc. in three replicates. No plant extract was added to the control. Results showed that *E. balsamifera* caused 96.67% adult mortality and *L. inermis* exerted 90.00% adult mortality after 14 days post treatment [13]. *C. odorata* root powder has also record effective mortality effect on cowpea weevils which accounted for total mortality of *C. maculatus* after a 72-hour exposure period [14]. Another research shows that, 5g/100g each of *Carica papaya* leaf powder and *Anona muricate* seed powder of cowpea grains proved to be most effective in grain damage and also *Carica papaya* leaf powder and *Citrus sinensis* powder proved to be most effective on adult emergence and adult mortality of cowpea weevil at eight weeks of the storage. However, 5g actellic dust was the most effective in controlling grain damage while 5g *Carica papaya* leaf powder and 5g *Anona muricate* seed powder proved to be most effective in controlling grain damage among the natural phytochemical extracts of plants, adult mortality and number of eggs laid by cowpea weevil on the stored grains [15]. Bioassay results revealed that essential oils obtained from *O. syriacum*, *L. angustifolia*, *S. officinalis*, *F.vulgare* and *L. nobilis* plants, at 30.0 or 40.0 µg ml-1 air, resulted in 100% adult mortality of cowpea weevils. Insecticidal activity was increased in response to increased concentration of essential oil [16]. Essential oils extracted from Myrtaceae, Annonaceae, Lauraceae, Rutaceae, Lamiaceae, Zingiberaceae, and Asteraceae have shown repellent, Oviposition, insecticidal, and growth-reducing effects on *C. maculatus*. The compounds from these essential oils exert their activities on insects through either neurotoxic or receptor inhibition effects involving several mechanisms, notably through GABA, sodium-gated channel, octopamine synapses, and the inhibition of acetylcholinesterase [17].

Feeding Deterrence

Various plant extract has been recorded to have negative impact on biological traits like growth capacity, feeding and reproduction of C. maculatus. These extracts can be the results of direct adults mortality, repellency, inhibition of reproduction and growth inhibition [18]. Therefore, the present investigation addressed the demonstrated efficacy of many constituents of essential oils such as monoterpenes which are volatile and can penetrate between grains, enhancing the exposure of different stages of the pest to the treatment and conferring advantage to those botanical extracts.

Insecticidal activities of seven plant materials (1-5g/100g *Vigna unguiculata* seeds) showed that citrus peel powder, acacia leaf powder, hot pepper powder, ginger powder, occimum leaf powder, mahogany bark powder and mahogany wood ash demonstrated great inhibition in feeding and grain damage compared with the synthetic insecticide, pirimiphos-methyl dust (0.1-0.5g/100g *Vigna unguiculata* seeds) as standard. The effectiveness of the treatments in succession was mahogany wood ash> pirimiphos-methyl dust > ginger powder > hot pepper powder > mahogany bark powder > Occimum leaf powder > Acacia leaf powder > citrus peel powder [19]. *Petroselinum sativum*, essential oil-controlled C. maculatus in a concentration-dependent manner (concentration increases resulted in lower weight losses and better germination levels of beans) (See Table 2). The parsley essential oil significantly reduced the losses in bean weight and germination rate caused by C. maculatus [20]. The antifeedant potential of extracts of five natural plants; *A. sativum*, *C. millenii*, *M. myristica*, *X. aethiopica* and *Z. officinale* against *C. maculatus*, established that extracts of Ginger caused the strongest feeding deterrency against the insect pests with percentage feeding index of 43.9% [21]. Plant extracts from the family Meliaceae, Apiaceae and Zingiberaceae demonstrates a great feeding deterrency against *C. maculatus* compared to other families of plant.

Oviposition Effect

A number of researches have been conducted to control the reproduction of bean weevil, these researches are carried out in terms of the percent damage and mortality of eggs hatched, number of exit/entry holes on seeds and number of eggs laid. Several plants extract covariable degree of efficacy ranging from total elimination of cowpea weevil's presence or hindering their effect on the seeds, eliminating their occurrence by moderate to low or reduced number of weevils.

In general, the results from several researches have demonstrate important unexpected effects of phytochemicals (powders and essential oil) of plants tested on oviposition of *C. maculatus.* The powders and crushed leaves of *B. senegalensis, C. viscosa and H. spicigera* tested exhibited inhibitory and ovicidal effects on the egg-laying of cowpea weevil females [22, 24]. The inhibitory and ovicidal effects on the egg-laying of cowpea weevil females is dependent on dose of phytochemicals used, this hypothesis appears to be more important with fresh crushed leaves of *B. senegalensis and C. viscosa* [24]. The dry powders of *H. spicigera* without ever reaching 100%, have less than 50% ovicidal effects at 48 hours of exposure. A study on the effect of lemon fruit peel oil on the oviposition inhibition and F1 adult emergence were carried out with split plot design of six concentrations (0.25ml, 0.5ml, 0.75ml, 1.0ml, 1.5ml and 2.0ml) replicated four times on bambara groundnut, cowpea, and pigeon pea against C. maculatus. The mean developmental periods of cowpea weevil in the selected legumes showed significant differences while the percentage development of weevil was highest in cowpea (95%) [25]. A study on garlic (*A. ascalonicum*), peppermint (*M. piperita*) and chilies (*C. annuum*) discovered that *C. annuum* and *A. ascalonicum* had harmful effects on *C. maculatus* for all parameters measured. *M. piperita* also showed significant reduction in the F1 progeny of the cowpea weevils but with less effect on weevils than *C. annuum* and *A. ascalonicum* [5]. Another laboratory study shows maximum percentage of oviposition deterrence was observed in *J.* curcas leaf extract (64.16%), *B. juncea* seed extract (64.65%), *A. indica* seed extract (65.44%), custard apple leaf extract (65.95%) and custard apple seed extract (67.19%) at 5 per cent concentration (See Table 3) [26]. Furthermore, biological experiments were carried out to find the insecticidal activities of n-hexane leaf extract of Custard apple (*A. muricate*), Potato (*S. tuberosum*), Lemon grass (*C. citrates*), Congo Bololo (*V. amygddalina*), Peacock Flower (*C. pulcherima*) and Big-sage (*L. camara*) individually against *C. maculatus*. The six plants leaf extracts showed significant ($p \leq 0.05$) insecticidal activities relative to control by inhibiting oviposition and first filial generation progeny emergence, increasing repellant and mortality rate, and reducing seed mutilation. [27]. *Vigna unguiculata* seeds treated with the lowest concentration of Moringa leaf powder, shows a sharp reduction in egg deposition and decrease in number of eggs laid by the adults. This condition can be explained by the fact that using the lowest concentration of moringa leaf powder caused deterrence of the females to lay eggs [28]. A sublethal exposure to essential oils of dried flower bud of clove and bark of cinnamon shows a positive reduction in oviposition of cowpea weevil. Bioassays results have revealed that synthetic pyrethroid insecticide deltamethrin have similar insecticidal activities to essential oils. Furthermore, oil dosage increments are found to be directly proportionate to decrease in the growth rate and this result in reducing the losses in bean weight caused by *C. maculatus*, and at 20% of parent's exposure to essential oil, offspring emergence was almost stopped. Finally, significant oviposition damages were perceived only in couples where females were exposed (i.e., females exposed and exposed couples) to the LD_{20} of *S. aromaticum and C. zeylanicum* essential oils [29].

Grain Damage

Citrus peel powder has recorded the highest percentage grain damage of (36.00^{b}). The seeds treated with ethanoic extracts of *E. caryophyllus* gave zero seed loss at all doses while *E. camaldulensis* and *B. pinnatum* shows no seed losses at the highest doses of 5 ml. The seed loss recorded at lower doses ranged from 0.63 ± 0.02% by *B. pinnatum* to 12.63 ± 0.10% by *E. camaldulensis* [9]. *A. muricata* at 3 and 5% treatment concentrations, *V. amygdalina* at 5%, and *L. camara* at 3 and 5% had the lowest percentages of damaged seeds. These percentages were comparable and significantly ($P \leq 0.05$) different from that obtained from all the other treatments including control which has total seed damage effect. *L. camara* at 1% treatment dose and *V. amygdalina* at 3% treatment dose had similar percentage of seed damaged. There were no significant differences ($P \geq 0.05$) in percentage of seed damaged by 1, 3 and 5% *C. pulcherima* and the control (100%). All other treatments except *C. pulcherima* significantly reduced the percentage of damage caused by *C. maculatus* to *V. unguiculata.* [27]. Extracts from *T. diversifolia* and *R. Communis* drastically reduced infestation and subsequence damage of the treated cowpea seeds for a period of three months [11]. In general, plants from the family Rutaceae shows high level of seed damage and hence render seed loss, while low seed damage is recorded from the family of Crassulaceae, Myrtaceae and Annonaceae.

Safety Of Insecticidal Plant Extracts On Human Health

Despite the fact that natural products from plant and their product are used, they are not always safer than synthetic products. Just because a phytochemical of plant has been utilized for centuries does not mean it is safe or even desirable (See Table 4). Plants contain many toxins which are synthesized naturally by the plants, some of which we can utilize for pest control purposes. However, some of these toxins can cause substantial human or animal health effects, and many deaths have been reported [30]. However, these plant extract are not always subject to rigorous testing or formal registration to identify their toxicity and absorptive affinity on human [30]. Hence there is a need to carry more research on their effect on environment as well as human health. Therefore, it is very important to critically examine the concentration at which the plant extracts are used in the control of the pest as well as the safety precautions used, due to the facts the geographical location, season, soil nutrient plays a significant role in variation between phytochemicals in plants and hence one cannot assume same concentration to have similar effect. Likewise, some plant extracts are safer to human health than others, due to the compounds available in such plants.

Clove and cardamom are widely used as spice and also shows high effect in insect control have been demonstrated as safe for human health. [31]. Essential oils extracted from the family of Myrtaceae, Meliaceae, Lamiaceae, Lauraceae, and Asteraceae with a few exceptions have low toxicity on mammalian toxicity and their environmental persistence is short [17]. These essential oils have been approved due to the less toxicity effect of these materials. *Xylopia aethiopica* contains bioactive medicinal compounds that may be beneficial to health [32]. *A.nilotica* is used as a curative agent [33]. *O. basilicum* is recommended as plant of phytopharmaceutical significance [34]. *C. frutescens* has nutritional benefits and they are use as food additives and different therapeutic purposes [34]. Moringa leaves have reduced-risk effects and hence have no known negative side effects or toxic elements, therefore, it is completely safe for consumption [35]. The leaves extract of *Euphorbia balsamifera* was found to be practically nontoxic [36].

Table 1: Efficacy of various plant extract on Contact and Fumigant Toxicity Effect

SN	High Efficacy	Toxicity		Moderate Efficacy	Toxicity		Low Efficacy	Toxicity	
1	*Anona muricate* powder	59.33^e;8wks:5g	[15]	*Citrus sinensis* powder	34.66^d;8wks:5g	[15]	*Carica papaya* powder	28.66^e;8wks:5g	[15]
2	Tea tree (*Melaleuca alternifolia*)	100%: 24hrs.;16 µl /50 ml air	[1]	Cloves (*Syzygium aromaticum*)	94%: 24hrs.;4 µl /50 ml air	[1]	Jojoba (*Simmondsia chinensis*)	90%: 24hrs.;16 µl /50 ml air	[1]
3	Cinnamon (*Cinnamomum zeylanicum*)	100%: 24hrs.; 8 µl /50 ml air	[1]	lemongrass (*Cymbopogon flexuosus*)	0.0%: 24hrs.;10 µl /50 ml air	[1]	*C. retusa*	53.75%: 96hrs.; 4.0% w/v	[11]
4	Thyme (*Thymus vulgaris*)	100%: 24hrs.;16 µl /50 ml air	[1]	Eucalyptus (Eucalyptus *globulus*)	56%: 24hrs.;4 µl /50 ml air	[1]	*H. suaveolens*	66.25%: 96hrs.; 4.0% w/v	[11]
5	*T. diversifolia*	100%: 96hrs.; 4.0% w/v	[11]	*R. communis.*	82.50%: 96hrs.; 4.0% w/v	[11]	*Thuja orientalis*	55%: 96 hrs.; at 0.0625% v/v	[12]
6	*Nicandra physaloides* (sap)	90%: 96 hrs.; at 0.0625% v/v	[12]	*Citrullus colocynthis* (sap)	40%: 96 hrs.; at 0.0625% v/v	[12]	*Curcuma longa* (sap)	80%: 96 hrs.; at 0.0625% v/v	[12]
7	*Dodonaea viscosa*	60%: 96 hrs.; at 0.0625% v/v	[12]	*Sichinus terebinthifolius* (sap)	90%: 96 hrs.; at 0.0625% v/v	[12]	*Trema orientalis* powder/ (sap)	43%:8weeks;3.0g	[2],
8	*Lawsonia inermis*	LC_{50}:14 days=2.7 x 103ppm	[13]	Flame seed powder (*Peltophorum*)	50%:8weeks;3.0g	[2]	*Aleo vera* powder	50%:8weeks;3.0g	[2]
9	Neem oil (*Azadiracta indica)*	98%:8weeks;3.0g	[2]	Oregano (*Origanum syriacum L.*)	$LC_{50:24\,hrs}$=11.17 µg ml^{-1}	[16]	Fennel (*Foeniculum vulgare Mill.*)	$LC_{50:24\,hrs}$=17.46 µg ml^{-1}	[16]
10	Sage (*Salvia officinalis L.*)	$LC_{50:24\,hrs}$=8.79 µg ml^{-1}	[16]	Lavender (*Lavandula angustifolia L.)*	$LC_{50:24\,hrs}$=11.64 µg ml^{-1}	[16]	Laurel (*Laurus nobilis* L.)	$LC_{50:24\,hrs}$=13.59 µg ml^{-1}	[16]
11	Negro pepper (*Xylopia aethiopica)*	100%: 7 days; 5 ml, $LC_{50:96\,hrs.}$=43.8mg	[9] [10]	*Bryophyllum pinnatum,*	100%: 7 days; 5 ml	[9]	*Eugenia caryophyllus*	100%: 7 days; 5 ml	[9]
12	*Chromolaena odorata*	100%: 72 hrs.= 2.43g	[14]	*Eucalyptus camaldulensis*	100%: 7 days; 5 ml	[9]	*Allium sativum*	$LC_{50:96\,hrs}$=55.0mg	[10]
13	*Cordia millenii*	$LC_{50:96\,hrs.}$=36.3mg	[10]	*Monodora myristica*	$LC_{50:96\,hrs}$=47.5mg	[10]	Actellic dust	23.00^b;8wks:5g	[15]
14	*Zingiber officinale*	$LC_{50:96\,hrs}$=37.5mg	[10]	*Euphorbia balsamifera*	LC_{50}:14 days= 2.9 x 10^3ppm	[13]			
15				*C. lanceolatus* (sap)	45%: 96 hrs.; at 0.0625% v/v	[12]			

Table 2: Efficacy of various plant extract on feeding deterrence

SN	High Efficacy	Toxicity		Moderate Efficacy	Toxicity		Low Efficacy	Toxicity	
1	Parsley, (*Petroselinum sativum* L.)	100% deterrence; 45dys: 489.5 lL L^{-1} air. / 43.9% feeding index: 5dys: 0.5g/ml	[20, 21]	Manjack (*Cordia millenii*)	59.9% feeding index: 5dys: 0.5g/ml	[21]	Galic (*Allium sativum*)	61.6% feeding index: 5dys: 0.5g/ml	[21]
2	Ginger Rhizome (*Zingiber officinale*)	100% feeding deterrence; 12 weeks =1g. / 43.9% feeding index: 5dys: 0.5g/ml	[19, 21]	Occimum leaf powder (*Occimum basilicum* L)	100% feeding; 12 weeks: 2g	[19]	African nutmeg (*Mondora myristica*)	64.9% feeding index: 5dys: 0.5g/ml	[21]
3	Negro pepper (*Xylopia aethiopica*)	48.3% feeding index: 5dys: 0.5g/ml	[21]	Mahogany wood ash (*Khaya senegalensis)*	100% feeding; 12 weeks: 4g	[19]	Acacia leaf powder (*Acacia nilotica*)	100% feeding; 12 weeks: 4g	[19]
4	Mahogany bark powder (*Khaya senegalensis*)	100% feeding; 12 weeks: 1g	[19]	Hot pepper fruit (*Capsicum frutescens* L.)	100% feeding; 12 weeks: 4g	[19]	*Citrus sinensis* (Fruit Peel)	100% feeding; 12 weeks: 4g	[19]

Table 3: Efficacy of various plant extract on Oviposition control

SN	High Efficacy	Toxicity		Moderate Efficacy	Toxicity		Low Efficacy	Toxicity	
1	Clove (*Syzygium aromaticum)* (L.)	100% female oviposition impairements:9days:48.6 µL kg^{-1}	[29]	mustard seed extract	64.65% oviposition deterrence: 15days: 5%conc	[26]	Citrus peel oil (*Citrus sinensis*)	95% emergence of beetle:34 days:	[25]
2	Cinnamon (*Cinnamomum zeylanicum)* (L.)	100% female oviposition impairements:9 days:106.2 µL kg^{-1}	[29]	jatropha leaf extract	64.16% oviposition deterrence: 15days: 5%conc	[26]	*Hyptis spicigera*	78.1%Reduction in egg laying: 24hrs: 50µl	[22]
3	Low conc. *Moringa oleifera*	95.76 % oviposition deterrence: 72hrs:0.1gm		High conc. *Moringa oleifera*	11.44 % oviposition deterrence: 72hrs:1.0gm		*Caesalpinia pulcherima*	85.10% Adult emergence: 96 hrs: 5%conc	[27]
4	Chilies (*Capsicum annuum)*	80.83% Eggs Hatched:4days:0.25g	[5]	Garlic (*Allium ascalonicum)*	84.19% Eggs Hatched:4days: 0.55 g	[5]	Peppermint (*Mentha piperita*)	87.36% Eggs Hatched:4days: 0.035g	[5]
5	*Annona muricate*	35.75% Adult emergence: 96 hrs: 5%conc	[27]	*Solanum tuberosum*	49.56% Adult emergence: 96 hrs: 5%conc	[27]			
5	*Lantana camara*	30.56% Adult emergence: 96 hrs: 5%conc	[27]	*Cymbopogon citrates*	49.98% Adult emergence: 96 hrs: 5%conc	[27]			
6	custard apple seed extract	67.19% oviposition deterrence: 15days:	[26]	*Cleome viscosa*	100% not hatched eggs:48hrs: 76.9 g/L	[23]			

		5%conc							
7	custard apple leaf extract	65.95% oviposition deterrence: 15days: 5%conc	[26]						
8	neem seed extract	65.44% oviposition deterrence: 15days: 5%conc	[26]						
9	*Boscia senegalensis*	100% not hatched eggs: 10 days: 4 g/l	[24]						
	Vernonia amygddalina	26.20% Adult emergence: 96 hrs: 5%conc	[27]						

Table 4: Phytochemical component of plants

SN	Plant Species	Family	Chemical Component	References
1	Schrad Seed (*Citrullus colocynthis*)	Cucurbitaceae	Alkanoids, flavonoids and glycosides	[36]
2	Gaertn herb (*Nicandra physaloides*)	Solanaceae	β-sitosterol, stigmasterol, cholesterol and β-amyrin,	[12]
3	Radd leaves (*Schinus terebinthifolius*)	Anacardiaceae	Gallic acid, Ellagic acid, Catechin, and Epicatechin	[37]
4	*Curcuma longa* (L.) rhizomes	Zingiberaceae	Curcumin, Demethoxycurcumin, Bisdemethoxycurcumin	[38]
5	*Callistemon lanceolatus* (D.C.) leaves	Myrtaceae	Phytosterols, Coumarins, Quinones and Saponins	[39]
6	*Thuja orientalis* (L.) leaves	Cupressaceae	α-pinene, 3-carene, cedrol, β –Caryophyllene, α-Humulene, Terpinolene and Limonene	[40]
7	Jacq leaves *(Dodonaea viscosa)*	Sapindaceae	3, 5, 7- trihydroxy-4 –methoxyflavone, 5, 7, 4 -trihydroxy-3- 6-dimethoxyflavone, trimethoxyflavone (santin), and 3,4',5,7-tetrahydroxy flavone (kaempferol)	[41]
8	Tea tree (*Melaleuca alternifolia*)	Myrtaceae	4-terpineol, Terpinene, γ-Terpinene, Cineol, p-cymene, a-pinene, α-Terpineol, α-Terpinolene and α-pcyeme-8-ol	[42]
9	Cinnamon oil (*Cinnamomum zeylanicum*)	Lauraceae	Eugenol and β-caryophylene	[28]
10	Cloves oil (*Syzygium aromaticum*)	Myrtaceae	Eugenol and β-caryophylene	[28]
11	Lemongrass (*Cymbopogon flexuosus*)	Poaceae	Tannins, saponins, flavonoids, phenols, anthraquinones, alkaloids, deoxysugars	[43]
12	Thyme (*Thymus vulgaris*)	Lamiaceae	Terpinene-4-ol, Carvacrol, Thymol, Carvacrol methyl ether, α-Terpinene, α-pinene and p-cymene	[42]
13	Eucalyptus (*Eucalyptus globulus*)	Myrtaceae	Flavonoids, terpenoids, saponins	[44]
14	Jojoba (*Simmondsia chinensis*)	Simmondsiaceae	Saponins, tannins, alkaloids, steroids and glycosides	[45]
15	Charcoal-tree **(***Trema orientalis*)	Cannabaceae	Terpenoids, flavonoids, Tannin, phenol, Saponin and alkaloid	[46]
16	*Aloe vera* gel	Asphodelaceae	Alkaloid, saponin, flavonoid, tannin, steroid, glycocide, protein and amino acid	[47]
17	Flame tree (*Peltophorum*) seeds powder		Flavonoids, tannins, saponins, carbohydrates, terpenoids, phenols, curcumins and glycosides	[48]
18	Neem (*Azadiracta indica*) oil	Meliaceae	Flavanoids, saponins, tannin, reducing sugar, Phenolic compound, Carbohydrat es, alkaloids	[49]
19	Garlic (*Allium ascalonicum*)	Amaryllidaceae	Methylallyl disulfide and diallyl trisulfide	[50]
20	Peppermint (*Mentha piperita*)	Lamiaceae	Menthol, isomenthone, limonene and cineole	[51]
21	Chilies (*Capsicum annuum*)	Solanaceae	Capsaicin	[52]
22	Moringa (*Moringa oleifera)*	Moringaceae	Polyphenols	[34]
23	Rattleweed (*Crotalaria retusa)*	Fabaceae	Glycoside, Saponins, Alkaloids, Sterols	[53]
24	Pignut (*Hypis suaveolens)*	Labiatae	Saponin, tannin, flavonoid, alkaloid, cyanogenic glycoside, phenol and anthocyanin	[54]
25	Castor Oil plant (*Ricinus commonis)*	Euphorbiaceae	Tannin, saponin, alkaloid, phytate, oxalate, flavonoid, cyanogenic glycoside and phenol	[55]
26	Mexican sunflower *(Tithonia diversifolia)*	Asteraceae	alkaloids, saponins, glycosides, flavonoid, tannins, terpenoid and phenols	[56]
27	Chup-chup seed powder *(Anona muricata)*	Annonaceae	Alkaloids, saponins, terpenoids, flavonoids, coumarins and lactones, anthraquinones, tannins, cardiac glycosides, phenols and phytosterols	[57]
28	Pawpaw leaf powder *(Carica*	Caricaceae	Saponins and alkaloids	[58]

	papaya)			
29	Citrus peel powder *(Citrus sinensis)*	Rutaceae	Polymethoxylated flavones, O-glycosylated flavones, C-glycosylated flavones, O-glycosylated flavonols, O-glycosylated flavanones and phenolic acid	[59]
	Citrus Peel Oil *(Citrus sinensi)*	Rutaceae	ß – pinene and limonene	[25]
30	Parsley (*Petroselinum sativum)*	Apiaceae	α-pinene, β-pinene and myristicin	[20]
31	Oregano (*Origanum syriacum* L.)	Lamiaceae	Carvacrol (66.66%), p-cymene (12.5%), γ-terpinene (12.4%)	[16]
32	Fennel (*Foeniculum vulgare Mill.*)	Apiaceae	trans-anethole (79.17%), estragole (7.19%), limonene (6.61%)	
33	Laurel (*Laurus nobilis* L.)	Lauraceae	1,8-cineole (50.0%), α-terpineyl acetate (14.45%), sabinene (7.5%)	
34	Sage (Salvia officinalis L.,)	Lamiaceae	Camphor (30.46%), Thujone (24.27%), 1,8 cineole (22.06%)	
35	lavender (*Lavandula angustifolia* L.)	Lamiaceae	Linalyl acetate (35.66%), 1,8-cineole (32.65%), camphor (20,2%), lavandulyl acetate (6.19%)	
36	Manjack (*Cordia millenii*)	Boraginaceae	α-amyrins, betulin, octacosanol, lupeol-3rhamnoside, β-sitosterol, β-sitosterol3glucoside, pyrrolizidine alkaloids, coumarins, flavonoids, saponins, terpenes and sterols	[60]
37	African nutmeg (*Mondora myristica*)	Annonaceae	Alkaloids, saponins, flavonoid, tannins, and phenols	[61]
38	Negro pepper (*Xylopia aethiopica*)	Annonaceae	β-pinene, 1,8-cineol, α-terpineol, terpinene-4-ol, paradol, bisabolene and terpenes	[31]
39	Ginger (*Zingiber officinale*)	Zingiberaceae	Alkaloids, saponins, tannins, flavonoids, terpenoid and phlobotannins	[62]
40	*Eucalyptus camaldulensis*	Myrtaceae	Saponin, saponin glycosides, steroid, cardiac glycoside, tannins, volatile oils, phenols and balsam (gum)	[62]
41	*Eugenia caryophyllus*	Myrtaceae	Alkaloid, phenols, flavonoids, tannins and saponins	[63]
42	*Bryophyllum pinnatum,*	Crassulaceae	Alkaloids, triterpenes, glycosides, flavonoids, steroids, bufadienolides, lipids and organic acids	[64]
43	*Chromolaena odorata*	Asteraceae	Tannins, steroids, terpenoids, flavonoids and cardiac glycosides	[65]
44	*Solanum tuberosum*	Solanaceae	Phenolic acids, flavonoids, phytates, folates, anthocyanins and carotenoids	[66]
45	Jatropha leaf extract (*Jatropha* curcas)	Euphorbiaceae	Alkaloids, flavonoids, terpenoids, saponins, and tannins	[67]
46	West Indian lemon grass *(Cymbopogon citrates)*	Poaceae	Alkaloids,saponins, tannis, anthraquinones, steroids, phenols and flavomoids	[68]
47	*Vernonia amygddalina,*	Asteraceae	Alkaloids, tannins, flavonoids, saponins, triterpenoids, steroids, cardiac glycosides, and reducing sugar	[69]
48	*Caesalpinia pulcherima*	Fabaceae	Sterols, glycosides, alkaloids, triterpenoids, flavonoids, anthraquinones, carotenoids, tannins	[70]
49	*Lantana camara*	Verbenaceae	Phytosterols, glycosides, carbohydrates, phenolic compounds, saponins, alkaloids, flavonoids and tannins	[71]
50	Custard apple seed	Annonaceae	Tannins, alkaloids, flavonoids, fixed oils and phenols	[72]
51	Mustard (*Brassica juncea*) seed extract	Brassicaceae	phenolic acids, flavonoids, alkaloids, and tannins	[73]
52	*Boscia senegalensis*	Capparaceae	Sulfur containing compounds (methyl isothiocyanate)	[74]
53	*Hyptis spicigera*	Lamiaceae	α-pinene; β-caryophyllene	[75]
54	*Cleome viscosa*	Cleomaceae	Flavonoid; phenols	[76]
55	Balsam spurge (*Euphorbia balsamifera)*	Euphorbiaceae	Steroids/triterpenes, tannins, anthraquinones and cardiac glycosides	[35]
56	Henna tree *(Lawsonia inermis)*	Lythraceae	Carbohydrate, glycosides, tannins, phenolic compounds and gums and mucilage	[77]
57	Acacia leaf powder (*Acacia nilotica*)	Fabaceae	Alkaloid, tannin, saponin, glycoside, flavonoids and resins	[32]
58	Mahogany bark powder *(Khaya senegalensis)*	Meliaceae	4-O-Methyl mannose, n-Hexadecanoic acid, 9,12,15-Octadecatrienoic acid, Oleic Acid and Catechol.	[78]
59	Hot pepper powder (Capsicum frutescens L.)	Solanaceae	Phenolic acid and flavonoids	[79]
60	Occimum leaf powder (*Occimum basilicum* L)	Labiataceae or Lamiaceae	Hexadecanoic acid (8.37%), hepta - 9,10,11 - trienoic acid (17.04%), octadecenoic acid (8.37%), 5- (hydroxymethyl) heptadecane (13.75%), eicosane aldehyde (37.36%) and octadecyl vinyl ether (15.12%)	[33]

Conclusion

The literatures reviewed have indicates that research effort have been put in the last decade to revive the use of phytochemicals especially in the control of agricultural pest. Over 60 plants from 20 families have been subjected to both laboratory and field test for their insecticidal effects on *C. maculatus*. In conclusion, essential oils obtained from naturally growing plants across Africa and Asia revealed promising efficiencies for controlling *C. maculatus* adults. As we have shown, there are several plant families with different compounds which shows varied level of efficacy based on their mode of action as well as application. As a natural insecticide, plant extracts possess a wide range of desirable properties as alternative to synthetic pesticides because they are safer, have no toxicological effect against human and environment.

In addition, this review will give more insight to researchers on different plant extract which have wide insecticidal efficacy, economically effective and less toxic to health that may provide clue to the development of novel classes of insecticides from natural products. In summary, natural plant-derived substances have become an area of research interest by many researchers and there is a possibility of increase in sophisticated researches in this field over the next several years by chemists, bio- chemists, cell biologists, psychologists, entomologists, and eco- toxicologists at both laboratory and molecular level and that the application of bioinsecticides will also become an increasingly important branch of the protection of stored products against beetle pests.

Declaration of interests

There is no conflict of interest in any form of competing financial interests or personal relationships that could have appeared to influence the work reported in this review.

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