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Prospective Bioactive Compounds from *Vernonia amygdalina*, *Lippia javanica*, *Dysphania ambrosioides* and *Tithonia diversifolia* in Controlling Legume Insect Pests

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Abstract

Synthetic insecticides are widely known to control insect pest, but due to high operational cost, environmental pollution, toxicity to humans, harmful effect on non-target organisms and the development of insect resistance to this products, have created the need for developing alternative such as those involving the use of botanical pesticides to control insect pest. Bioactive compounds derived from plant could be an alternative source for insect pest control because they constitute a rich source of natural chemicals. This review aims to explore the potential of plant bioactive compounds from Vernonia *amygdalina*, *Lippia javanica*, *Dysphania ambrosioides* and *Tithonia diversifolia* as a low-cost, safe and environmentally friendly means of controlling insect pests in legumes.

Keywords

Common Bean, Secondary Metabolites, Alkaloids, Sesquiterpene, Flavonoids, Limonoids, Phenols

1. Introduction

Currently, different kinds of control measures are practiced to protect grain legumes from insect pests attack. Among those, synthetic pesticides such as organ chlorines, organophosphates, carbamates, pyrethroids and neonicotinoids have been considered to be the most effective and easy to use against insect pests [1]. Although these

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methods are effective, their repeated use for several decades has its consequences. It has been estimated that about 2.5 million tons of pesticides are used on crops each year and the worldwide damage caused by pesticides reaches $100 billion annually [2].

The knowledge that plants exhibit pesticidal properties has been known and used for protecting crop legume and other foodstuffs [3]. Plants from different families, genus and species are known to have very rich source of bioactive organic chemicals and more than 400,000 secondary metabolites may be present in the plant kingdom [4]. In the middle of the 17^{th} century, pyrethrum, nicotine and rotenone were recognized as effective insect control agents for their pesticidal activities [5]. Alkaloids, sesquiterpene, flavonoids, limonoids, phenols, coumarins, and stilbenes of plant origin are known to possess toxic, antifeedant, reperrence and growth regulating effects against a wide range of insect pests including common bean insect pests [6] [7]. The use of plants bioactive compounds in the form of pesticidal treatments has many advantages and some of them are effective, environmentally friendly, less hazardous to human and animal health, cheap, non-toxic to non-target species, and less likely to result in resistance in the target organism [8]-[12].

Synthetic modification of phytochemical has resulted in more effective and improved bioactive compounds [13]. Synthetic pyrethroids such as cypermethrin, cyahalothrin and deltamethrin based on the natural pyrethrum structural models, have become quite popular and occupy a large share of the pesticide market, mainly because of their broad-spectrum activity and low mammalian toxicity. The most economically important of the natural plant compounds used in commercial insect control are the pyrethrins from the flower heads of pyrethrum *Chrysanthemum cinerariaefolium* [14]. Nicotine isolated from number of species of *Nicotiana* is also insecticidal. Botanical products like tobacco extract, neem oil and extract, which can be easily and cheaply collected in rural farmers, have been found promising and useful for common bean pest control [15]-[17]. Likewise the bioactive compounds of *Tephrosia vogelii*, *Azadirachta indica*, *Annona squamosa*, chilli paper *Allium sativa* have been used successfully in controlling insect pests in common beans and cowpea [18]. Due to the need for the alternative to synthetic insecticide, there is a need of evaluating the potential compounds from locally available plant materials known to possess insecticidal properties such as *Vernonia amygdalina*, *Lippia javanica*, *Dysphania ambrosioides* and *Tithonoa diversifolia.* These plants have showed effectiveness in insect pest control, for example *Vernonia amygdalina* have been used to control cowpea bruchid, fungal disease in cowpea and vegetable pests [19], *Lippia javanica* have been used in controlling aphid population on cabbage (Brassica capitata by 24.65%. The plant also has antibacterial, antifungal, antiprotozoal and insect-repellent activity and seems to repel antestia bugs [20]. *Dysphania ambrosioides* have both repellency and insecticidal which was observed in controlling bean bruchid especially *Z. subfasciatus* in stored haricot bean. The extract also was observed in controlling aphids in tomato [21]. Likewise *Tithonoa diversifolia* have been identified to have insect feeding deterrent characteristics due to presence of 6-methoxyapigenin and to have tagitinins A, B, C and F, with diversiform, tirotundin, tithonine and sulphurein [22]. There are few reports on insecticidal investigations concerning these plants. Therefore, there is a need of exploiting more about the potential of these plants in controlling insect pests causing damage to common bean.

2. Some of the Isolated Compounds from *Vernonia amygdalina* and Possible Effects of Their Plant Extract in Controlling Common Bean Insect Pests

Vernonia amygdalina, a member of the Asteraceae family, is a small shrub that grows in the tropical Africa with petiolate leaf of about 6 mm diameter and elliptic shape (**Figure 1**). It is commonly called "bitter leaf" because of its bitter taste. The bitterness can, however, be abated by boiling or by soaking the leaves in several changes of water. The bitter taste is due to anti-nutritional factors such as alkaloids, saponins, tannins, and glycoside [23]. The plant has being used traditionally to treat sexually transmitted diseases such as gonorrhea and malaria in rift valley and western parts of Kenya [24] and cancer cells [25]. *V. amygdalina* may provide anti-oxidant benefit [26]. The aqueous extract of this plant have been found to have cell growth inhibitory effects in prostate cancer cell line [27] [28]. The plant has antihelmintic, antitumorigenic, hypoglycaemic and hypolipidaemic activity and both the leaves and the roots are used traditionally in phytomedicine to treat fever, kidney heart disease and stomach discomfort [29]. Many studies have shown that *V. amygdalina* extracts may strengthen the immune system through many cytokines (including NFκB, pro inflammatory molecule) regulation [30].

Several investigators have isolated and characterized a number of chemical compounds with potent biological activities from the leaves of *Vernonia amygdalina*. Some of the previously isolated constituents in *Vernonia*

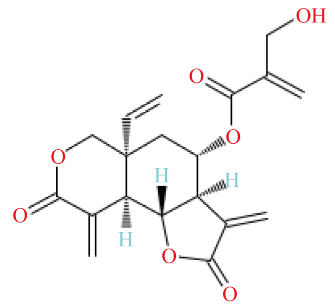
Figure 1. Botanical image of *Vernonia amygdalina*.

amygdalina include: sesquiterpene lactones [31], terpenoids, flavonoids like luteolin, luteolin 7-O-glucosides and luteolin 7-O-glucuronide [32], steroid glycosides [26] [33], saponin, terpenoids and vernonioside A, B, A1, A2, A3, B2, B3 and A4 which observed to regulate growth of *Streptococcus mutans* and *Staphylococcus aureus* and common bean insect pests in field [34]. *V. amygdalina* also have reported to contain large quantity of Thiamine, Pyridoxine, Ascorbic acid, Glycine, Cysteine and Casein hydrolysate significantly more than other botanicals such as *Bryophyllum pinnatum*, *Eucalyptus globules* and *Ocimum gratissimum* [35]. Other studies have confirmed that *V. amygdalina* have toxic compounds to common bean aphids [36]. The most well isolated compound with the active ingredients being specified as sesquiterpene lactones containing vernodalin, vernodalol and 11, 13-dihydrovernodalin, these have insecticidal properties which act as an insect feeding deterrent [37] as shown in **Figures 2(a)-(c)** below. The essential oils extracted through hydro distillation of the leaves of *V. amygdalina* contained eucalyptol (1, 8 cineole, 25%), beta pinene (14.5%), myrtenal (6.5%) (**Figures 2(d)-(f)**) and other minority constituents while essential oil from its aerial part contained mainly alpha-muurolol (45.7%) [6]. Other essential oil of *V. amygdalina* (0.3%) was able to protect maize from the maize weevil *Sitophilus zeamais* by reducing the number of weevil progeny production and by evoking a high repellant action against weevil without damaging the grain. The presence of these difference bioactive compounds used for various purposes in *V. amygdalina* attracts researchers to quantify the efficacy of this plant in controlling insect pests such as those damaging common bean.

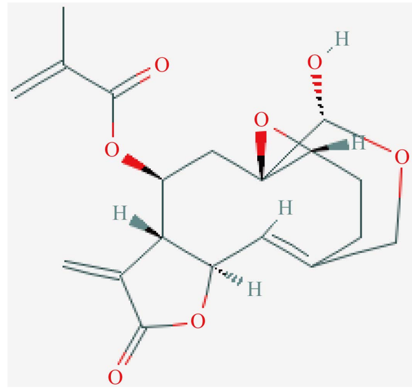
3. Some of the Isolated Compounds from *Lippia javanica* and Possible Effects of Their Plant Extract in Controlling Common Bean Insect Pests

Lippia javanica is known as fever tea/lemon bush and has dense creamy white, flower heads (**Figure 3**). It grows in open veld, in the bush, grassland on hillsides and stream banks, and as a constituent of the scrub on the fringes of forest. The plant is widely distributed in Zimbabwe, Ethiopia, East Africa and South Africa. Most of them are traditionally utilized as gastrointestinal and respiratory remedies [38]. Some *Lippia* species have shown antimalarial, antiviral and cytostatic activities [39]. A study conducted in Kenya by [39] found that the essential oils from *Lippia* species demonstrated a larvicidal activity against *Aedes aegypti* larvae and a maize weevil (*Sitophilus zeamais*). Similarly, *L. javanica* was reported to have pesticidal effects on aphids, ticks, antestia bugs and red spider mites on rape [40].

The chemistry of the volatile oil of *L. javanica* contains several terpenoids of which 3-methyl-6-(1-methylethylidene)-cyclohex-2-en-1-one (1) was the major component and the results suggested that the oil was effective in inhibiting cultures of *Escherichia coli*, *Bacillus subtilis* and *Staphylococcus aureus*. The plant is also used as mosquito repellent [41]. As an insecticidal and medicinal plant, different chemo types have been identified which includes; Piperitenone, mycene, myrcenone, carvone, limonene and linalool (**Figures 4(a)-(f)**), with the major one being myrcenone and piperitenone [39]. Other chemical constituents of the essential oil of *L. javanica* such as alpha-pinene, sabinene, myrcene and 1, 8 cineole, have been identified as a repellant against insect pests [42]. *L. javanica* have also been evaluated to contain toxic substances against many microbes and insect pest [43]. Further studies on *L. javanica* should focus on of the occurrence of new chemotypes in natural plant populations and the impact that this would have on controlling common bean insect pest.



(a)



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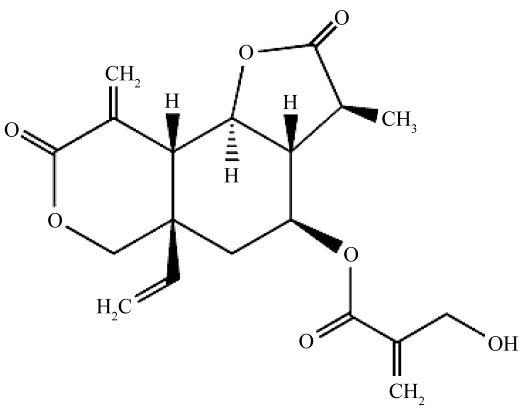

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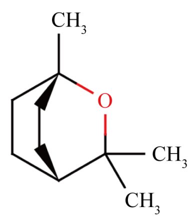

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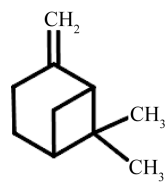

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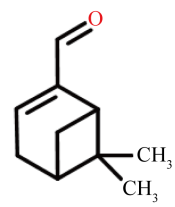

(f)

Figure 2. (a) Structure of vernodalin. http://pubchem.ncbi.nlm.nih.gov/summary/summary.cgi?sid=11767, accessed 10/07/2014 at 1642 hrs; (b) Chemical structure of Vernolide http://pubchem.ncbi.nlm.nih.gov/summary/summary.cgi?sid=11774&viewopt=PubChem, accessed on 10/07/2014 at 1650 hrs; (c) Structure of 11, 13-dihydrovernolidalin. http://pubchem.ncbi.nlm.nih.gov/summary/summary.cgi?cid=23786372, Accessed on 10/07/2014 at 1705 hr; (d) Structure of cineole with chemical formula $C_{10}H_{18}O$. https://www.google.com/search?client=firefox-beta&rls=org.mozilla%3Aen-US%3Aofficial&channel=np&biw=1366&bih=634&noj=1&sclient=psy-ab&q=Structure+of+cineole&oq=Structure+of+cineole&gs_l=serp.3...3063.9041.1.9721.30.15.0.0.0.0.0.0..0.0....0...1c.1.49.serp..30.0.0.E26Q-wU4nLA, accessed on 10/07/2014 at 1105 hrs; (e) Structure of beta pinene with chemical formula $C_{10}H_{16}$. http://www.chemspider.com/Chemical-Structure.14198.html, accessed on 22/07/2014 at 1434 pm; (f) Structure of Myrtenal with chemical formula $C_{10}H_{14}O$. http://www.chemspider.com/Chemical-Structure.55078.html, accessed on 22/07/2014 at 1439 hr.

Figure 3. Botanical image of *Lippia javanica*.

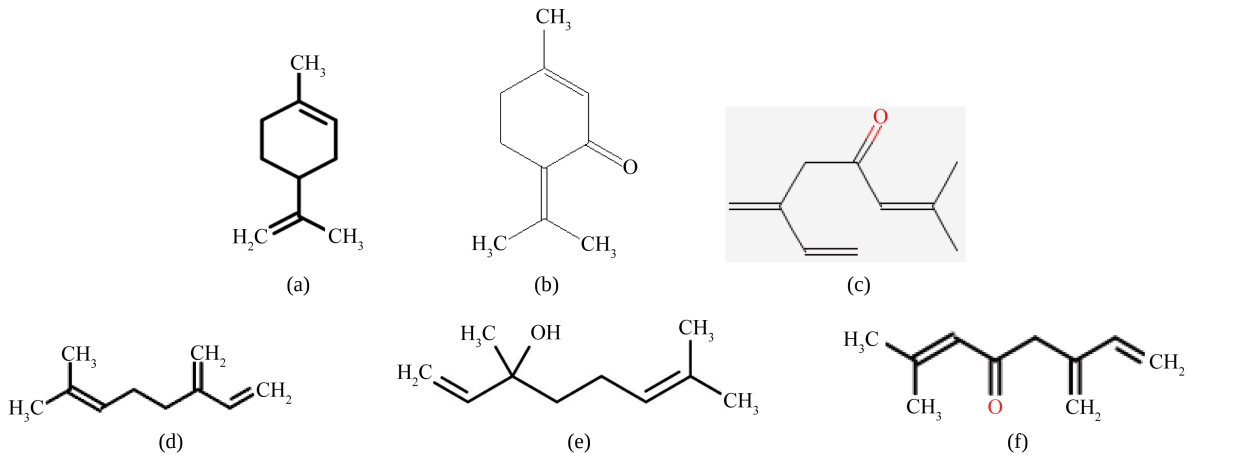

Figure 4. (a) Limonene structure with chemical formula $C_{10}H_{16}$. http://www.chemspider.com/Chemical-Structure.20939.html, accessed on 15/07/2014 at 1630 hrs; (b) Piperitenone structure with chemical formula $C_{10}H_{14}O$. https://www.google.com/search?q=structure+of+Piperitenone&client=firefox-beta&rls=org.mozilla:en-US:official&channel=np&noj=1&tbm=isch&tbo=u&source=univ&sa=X&ei=b0_OU4O_DuWS7Aa2w4HwCQ&ved=0CEMQ7Ak&biw=1366&bih=634, accessed on 22/07/2014 at 1452 hrs; (c) Myrcenone structure with chemical formula $C_{10}H_{14}O$. http://www.pherobase.com/database/compound/compounds-detail-myrcenone.php, accessed on 15/07/2014 at 1642 hrs; (d) Mycene structure with chemical formula $C_{10}H_{16}$. http://www.chemspider.com/Chemical-Structure.28993.html, accessed on 22/07/2014 at 1458 hrs; (e) Linalool structure with chemical formula $C_{10}H_{16}O$. http://chemistry.about.com/od/factsstructures/ig/Chemical-Structures---L/Linalool.htm, Accessed on 22/07/2014 at 1522hrs; (f) Mycenone structure with chemical formula $C_{10}H_{18}O$. http://www.chemspider.com/Chemical-Structure.4936165.html, accessed on 22/07/2014 at 1514 hrs.

4. Some of the Isolated Compounds from *Dysphania ambrosioides* and Possible Effects of Their Plant Extract in Controlling Common Bean Insect Pests

D. ambrosioides (L.), traditionally named "Epazote" is a perennial plant native to South America (**Figure 5**) [41]. *D. ambrosioides* is used as a leaf vegetable and herb for its pungent flavor and its claimed ability to prevent flatulence caused by eating bean and other South American dishes [44]. This plant is known as an anthelmintic, vermifuge, and emmenagogue [45]. Extracts of *D. ambrosioides* are composed of many constituent ingredients with many historical medicinal uses. Traditionally, the plant extract is used in the treatment of diarrhea [46], dysmenorrheal, malaria, chorea, hysteria, catarrh, asthma and certain cancer cell lines The plant has also been reported to exhibit antipyretic, antifungal, antiviral, antibacterial, sedative, analgesic, antioxidant and insecticidal activities [47] [48]-[51]. It has also been reported to be highly carcinogenic in rats [52]. The plant is commonly believed to prevent flatulence. In the laboratory studies, some of its chemical constituents have shown to affect certain cancer cell [53]. The plant is still used to treat worm infections in humans in many countries [53].

As a pesticidal and medicinal plant, the extract is used for its properties as an insecticide and acaricide. The extract of *D. ambrosioides* were observed to control bean bruchid especially *Z. subfasciatus* in stored common bean [54]. In field studies, theirs extract also were effective in controlling aphids in tomato [54]. Few active compounds including: ascaridole, 2-carene, ρ-cymene, isoascaridole, α-terpinene (**Figures 6(a)-(d)**) and isoascaridolnene have been isolated from the plant. The major one being ascaridole which may constitute 40% - 70% of the total active compounds in *D. ambrosioides* [55].

Ascaridole (also known as ascarisin; 1, 4-epidioxy-p-menth-2-ene) is a bicyclic monoterpene that has unusual bridging peroxide functional group. These were isolated and identified as important medicinal and insecticidal compounds [55]-[57]. A study from the University of California [58] found that the compound ascaridole in *D. ambrosioides* inhibits the growth of nearby plants. Therefore, the active constituents from this plant may play critical role(s) as a pesticidal candidate and hence more researchers are recommended to quantify its potential.

5. Some of the Isolated Compounds from *Tithonia diversifolia* and Possible Effects of Their Plant Extract in Controlling Common Bean Insect Pests

Tithonia diversifolia A. Gray (Astera-ceae, tribe Heliantheae) is a prolific shrub, perennial and erect, native to

Figure 5. Botanical image of *Dysphania ambrosioides*.

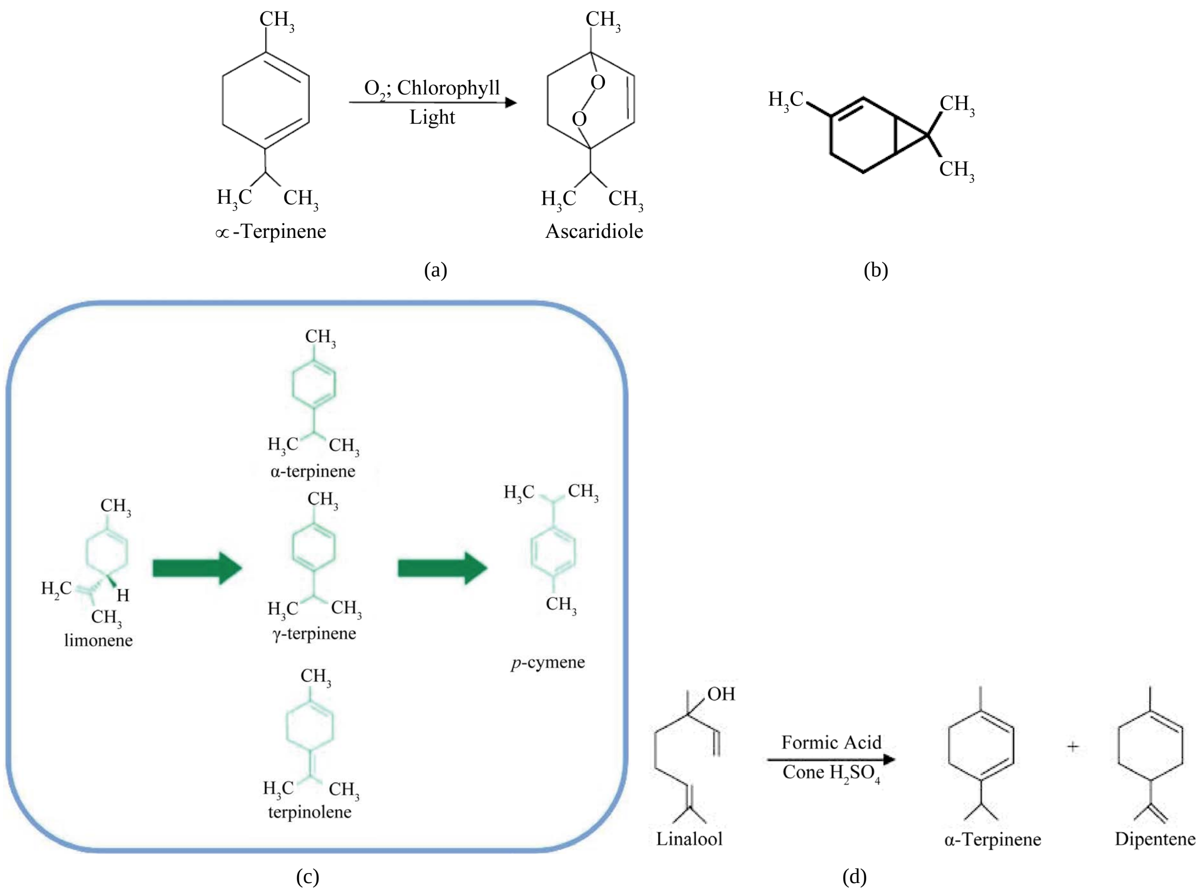

Figure 6. (a) Synthesized of ascaridole from µ-terpinene by treatment with oxygen, chlorophyll and light. https://www.google.com/search?client=firefox-beta&rls=org.mozilla:en-US:official&channel=np&noj=1&tbm=isch&source=univ&sa=X&ei=N1jOU5-COOSO7QaK2IGwDw&ved=0CFkQ7Ak&biw=1366&bih=634&q=structure%20of%20ascaridole; (b) 2-carene structure with chemical formula $C_{10}H_{16}$. http://www.chemspider.com/Chemical-Structure.24263.html, accessed on 22/07/2014 at 1537 hrs; (c) Conversion of limonene to p-cymene and reaction intermediates, Source: [59]; (d) Formation of a-terpinene and other monoterpene. https://www.google.com/search?q=structure+of+a-terpinene&client=firefox-beta&rls=org.mozilla:enUS:official&channel=np&noj=1&tbm=isch&tbo=u&source=univ&sa=X&ei=dFvOU67UKrPH7Aa6g4HICw&ved=0CE0Q7Ak&biw=1366&bih=634, accesed on 16/07/2014 1452 pm.

Mexico and Centra America, and introduced in Africa, Australia, Asia and South America (**Figure 7**) [60]. It is widely cultivated as an ornamental shrub and for its medicinal value in different regions where it is commonly known as Mexican sunflower or tree marigold, as well as "nitobegiku". In folk medicine, the aerial parts of *T. diversifolia* are of value for the treatment of diabetes and malaria [61] and infectious diseases [62]. The species is of particular interest for phytomedical and health care research since it has shown diverse pharmacological activities, such as antiplasmodial [63], antiamoe-bic, antiviral, anti-inflammatory and antidiabetic [64].

Concerning the phytochemical analysis, the non-volatile fractions of *T. diversifolia* are a rich source of flavonoids and sesquiterpene lactones, while the essential oil comprises predominantly monoterpene hydrocarbons, such as b-ocimene, a-pinene and limonene. The plant have been identified to have insect feeding deterrent characteristics due to presence of 6-methoxyapigenin and to have tagitinins A, B, C and F, with diversiform, tirotundin, tithonine and sulphurein (**Figures 8(a)-(d)**). The bioactive compounds such as sesquiterpene lactones, tagitinin A, tagitinin C and a flavonoid hispidulin isolated from *Tithonia diversifolia* were also found to have regulatory effects on germination of radish, cucumber and onion seeds [65]. Tagitinin C, a sesquiterpene lactone, has been reported as the main antiplasmodial constituent of the plant [66] which is found from the leaves. Although many studies on *T. diversifolia* have been carried out in different research fields [67], there are few reports on plant insecticidal investigations. Therefore, there is a need of exploiting more about the potential of this plant in controlling common bean insect pests. **Figures 8(a)-(d)** below show some of the isolated bioactive compounds from the *T. diversifolia* plant.

Figure 7. Botanical image of *Tithonia diversifolia.*

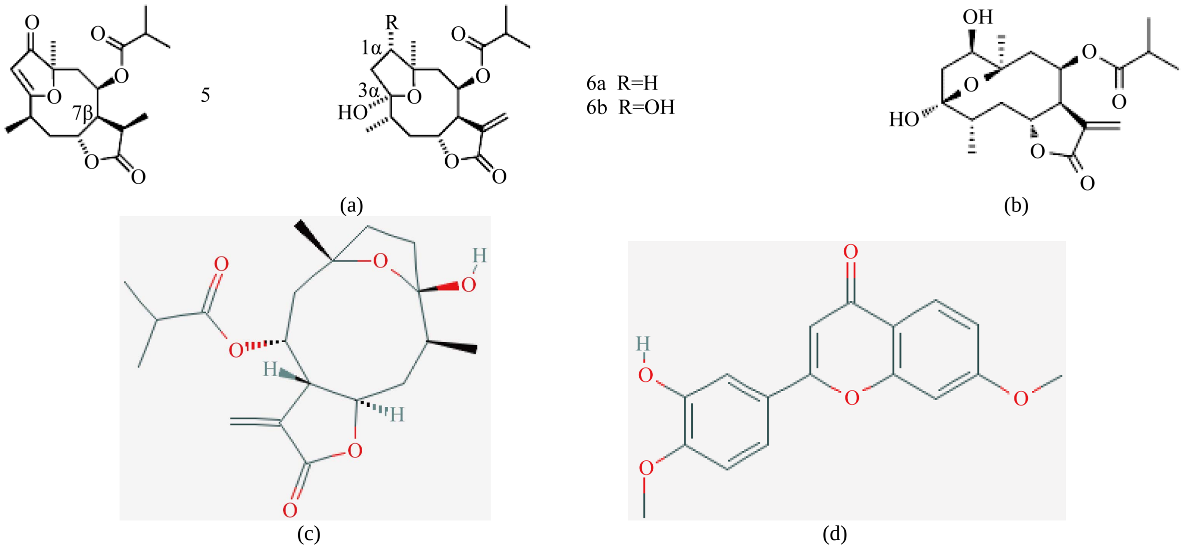

Figure 8. (a) Tagitinin A structure with chemical formula, Source: [68]; (b) Tagitinin C structure, Source: [69]; (c) Tirotundin structure with chemical formula $C_{19}H_{28}O_6$. http://pubchem.ncbi.nlm.nih.gov/summary/summary.cgi?cid=9975297 accessed on 22/07/2014 at 1557 hrS; (d) Tithonine structure with chemical formula $C_{19}H_{28}O_6$. http://pubchem.ncbi.nlm.nih.gov/summary/summary.cgi?sid=85293707&viewopt=PubChem, accessed on 22/07/2014 at 1556 hrs.

6. Conclusion

In conclusion, the use of bioactive compounds from plant as an insecticide is believed to be a promising strategy in controlling legume pests in the field and storage at a reasonable cost. Due to inadequate information about the importance of these insecticidal plants to farmers, there is a need of testing them widely to ascertain their potential and finally disseminate useful information on their validity to farmers in order to overcome the use of synthetic insecticide in controlling crop insect pest.

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