

Review paper

A Review on the Biological activity and the triterpenoids from the Genus *Vernonia* (Asteraceae Family).

Medicinal plants have always played a key part in health care. In fact, plants represent an enormous pool of new, undiscovered, and bioactive molecules. Therefore, ethnopharmacological and ethnobotanical studies are essential to discover new substances for the treatment of diseases. The *Vernonia* genus has about one thousand species and members of the genus are widely used as food and medicine. The plant-derived triterpenoids are commonly used for medicinal purposes in many countries, because they possess various pharmacological properties. A large number of triterpenoids are known to exhibit cytotoxicity against a variety of tumor cells as well as anticancer efficacy in preclinical animal models. Therefore this review presents an overview of *Vernonia* species with their biological potential, ethnomedicinal uses and the triterpenoids isolated from this genus. This will help to identify the state of ethnopharmacological knowledge in regard to this genus and to propose future research priorities.

Keywords: *Vernonieae*, biological activity, phytochemistry, triterpenoids.

Introduction

Vernonia is one of the largest genera of flowering plants in the Asteraceae family, which includes more than 1500 species distributed widely in the tropical and sub-tropical region of Africa, Asia and America. Ethnomedicinally, species of the genus *vernonia* are used in the treatment of infectious and parasitic diseases. The infectious diseases range from those affecting the skin to those of the stomach (gastrointestinal infections). Other major applications include treatment of bacterial infections, gynaecological diseases and complications, respiratory diseases, diabetes, urinary tract infections and venereal diseases. Parasitic diseases include malaria, worm infection, amoebiasis and schistomiasis. Some species are also used as antivenom against snakebites and insect bites.

METHODOLOGY

The current review was achieved using an designed search of the scientific data published about antimicrobial activity, focusing on the antibacterial and antifungal activities of the species of the genus *Vernonia*. The searches were carried out using various databases, including PubMed (<http://www.ncbi.nlm.nih.gov/pubmed>), Science Direct (<http://www.sciencedirect.com/>), Scopus (<http://www.scopus.com/>), Scielo(<http://www.scielo.org/>), GoogleScholar (<http://www.scholar.google.com/>) and scifinder 2009.

Biological activity of the genus *Vernonia*

Among the diverse biological activities, antibacterial studies are the most reported in the genus *vernonia*. Antibacterial activity was found to be common to all species in all extracts followed by analgesic, antipyretic, anti-inflammatory and antiparasitic activity. Antibacterial compounds are mainly lipophilic and will partition from an aqueous phase into bacterial membrane structures, causing expansion of the membranes, increased fluidity, disordering of the membrane structure and inhibition of membrane embedded enzymes (Sikkema *et al.*, 1995). Antifungal activity is also reported in five of the *Vernonia* species, while antiviral is not commonly reported in the *Vernonia* with only one report in the ethanol extract of the fruit of *V. amagdalina*.

Of the *Vernonia* species, *V. amygdalina* appears to be the most widely used. The leaves are the most commonly used plant part and is prepared as a decoction. In some cases a decoction of the whole plant is prepared. The method of preparation depends on the application, for example, a mixture of the root and leaf decoction is drunk to treat gastrointestinal diseases and as an antipyretic and the leaves soaked in alcohol is drunk to treat diabetes mellitus. The traditional medicinal applications of members of the genus are illustrated in Table 1.

Table 1 Species of *Vernonia* used in traditional medicine

Plant species	Plant part	Traditional use	References
<i>V. ambigua</i>	Whole plant	Antimalarial	Builders <i>et al.</i> , 2011
<i>V. amygdalina</i>	leaves	antimalarial, antidiabetic, antipyretic, gastrointestinal diseases, appetite stimulant, dermatological infections, antihelminthic, respiratory tract infections, gynaecological	Akah and Okafor 1992; Akah and Ekekwe 1995; Yeap <i>et al.</i> , 2010; Huffman <i>et al.</i> , 1993

		diseases and complications, infertility, antibacterial, antifungal and antivenom (snake bite)	
	stems	anti-HIV, antiviral and anti-amoebic	Yeap <i>et al.</i> , 2010
	leaves and fruits	antimalarial, antihelminthic, antibacterial and antiviral	Yeap <i>et al.</i> , 2010; Erasto <i>et al.</i> , 2006
	roots	venereal diseases and gynaecological complications	Yeap <i>et al.</i> , 2010; Geissler <i>et al.</i> , 2002
<i>V. antihelminthica</i>	seeds	antihelminthic, respiratory diseases, gastrointestinal diseases and complications, diuretic, anti-inflammatory, kidney protection and anti-ulcer	Otari <i>et al.</i> , 2010
<i>V. auriculifera</i>	Leaves and roots	Antipyretic, antivenom, eye infections	Muthaura <i>et al.</i> , 2007
<i>V. branchycalyx</i>	roots	gastrointestinal complication	Oketch-Rabah <i>et al.</i> , 1997
<i>V. cinerea</i>	leaves and roots	antihelminthic, astringent, conjunctivitis, dermatological diseases, diuretic, antipyretic, gastrointestinal diseases, gynaecological diseases, respiratory diseases, antidote and urinary tract diseases	Deborah <i>et al.</i> , 1992; Khare, 2007; Marita <i>et al.</i> , 1999; Misra <i>et al.</i> , 1993
<i>V. colorata</i>	leaves	dermatological infections, respiratory diseases, antidiabetic, gastrointestinal diseases, antipyretic, antiviral (hepatitis) and venereal diseases	Cioffi <i>et al.</i> , 2004; Rabe <i>et al.</i> , 2002; Sy <i>et al.</i> , 2004
<i>V. condensata</i>	leaves	analgesic, anti-ulcer, anti-diarrhoea, gastrointestinal diseases, liver protection and antivenom (snakebites)	Frutuoso <i>et al.</i> , 1994; Pereira <i>et al.</i> , 1994
<i>V. conferta</i>	bark	anti-diarrhoea (bloody)	Aliyu <i>et al.</i> , 2011
<i>V. cumingiana</i>	ns	antirheumatic arthritis, antiviral, bone and muscular injury, respiratory diseases, antimalarial, and dental diseases	Lin <i>et al.</i> , 1985; Zhonghuabencao, 1999
<i>V. ferruginea</i>	ns	anti-inflammatory remedies	Malafrente <i>et al.</i> , 2009
<i>V. galamensis</i>	leaves	antidiabetic (mellitus) and gastrointestinal diseases	Chhabra <i>et al.</i> , 1989
<i>V. guineensis</i>	ns	antidote to poison, aphrodisiac, jaundice, anti malarial and prostatitis	Tchinda <i>et al.</i> , 2002
<i>V. jugalis</i>	bark	anti-diarrhoea (bloody)	Aliyu <i>et al.</i> , 2011
<i>V. kotschyana</i>	roots	abdominal pains, respiratory diseases including TB, antibacterial, dermatological infections, gastrointestinal disorder, analgesic, antiparasitic, antiprotozoa and anti-ulcers	Sanogo <i>et al.</i> , 1998; Nergard <i>et al.</i> , 2004
<i>V. mapirensis</i>	ns	anti-inflammatory	Morales-Escobar <i>et al.</i> , 2007

<i>V. nigrifolia</i>	root	diuretic, gastrointestinal infections, emetic, antipyretic and antihelmintic	Aliyu <i>et al.</i> , 2011
<i>V. nudicaulis</i>	whole plant	venereal diseases	Aliyu <i>et al.</i> , 2011
<i>V. pachyclada</i>	ns	dermatological injury	Williams <i>et al.</i> , 2005
<i>V. paltula</i>	whole plant	antimalarial, antirheumatic and gastrointestinal infections	Chiu and Chang, 1987
	leaves	antiamoebic, antihelmintic, antiviral, respiratory tract infection, gastrointestinal infections and dermatitis	Gani, 1998
	roots	gastrointestinal infections, respiratory tract infection and colic	Gani, 1998
	flowers	eye problem, antipyretic and antirheumatic	Mollik <i>et al.</i> , 2010 Gani, 1998
	seeds	antihelmintic, gastrointestinal disorder, urinary tract infection and dermatological infection	Gani, 1998
<i>V. polytricholepis</i>	ns	antipyretic and respiratory infections	Aliyu <i>et al.</i> , 2011
<i>V. potamophila</i>	leaves	anticancer and skin infection	Babady-bila <i>et al.</i> , 2003
<i>V. saligna</i>	ns	respiratory tract infections and gynaecological complications	Huang <i>et al.</i> , 2003
<i>V. scorpioides</i>	leaves	dermatological infection (diabetic lesions) and anti-ulcer	Pagno <i>et al.</i> , 2006; Buskuhl <i>et al.</i> , 2010
<i>V. trichoclada</i>	ns	anti-inflammatory	Morales-Escobar <i>et al.</i> , 2007
<i>V. tweediana</i>	ns	respiratory tract diseases	Zanon <i>et al.</i> , 2008
<i>V. urticifolia</i>	laeves	Dermatological infection, antimalarial, respiratory infection, antihelmintic, alimentary infection.	Anoka <i>et al.</i> , 2008; Misra <i>et al.</i> , 1984

Key: ns-not specified

In rural areas where access to healthcare is not readily available, people rely on these extracts for common pain relief, inflammation and fever. Four of the nineteen species have also been reported to have antiparasitic activity, either antiparasmodial, antileishmanial, antischistomatic, anti-amoebic or antihelmintic. These are mainly reported for the polar extracts such as the aqueous and methanol extracts with few reports being in the chloroform or hexane extract.

Beside the antibacterial, antiparasitic and conditions associated with pain, inflammation and fever, extracts of these plants have also shown other activities such as antidiabetic, antioxidant, anticancer, antiulcer, immunomodulatory, pesticidal and insecticidal activity.

The most extensively studied plant among all the *Vernonia* species is *V. amygdalina*, reported to possess several pharmacological activities such as antidiabetic, antibacterial, antimalarial, antifungal, antioxidant, liver protection and cytotoxic effects (Table 2). The biological activities of *Vernonia* species that have been studied and documented are listed in table 2.

Table 2: Biological activities of extracts from *Vernonia*

Plant species	Biological activity	Extract	Reference (s)
<i>V. ambigua</i>	antibacterial	ethanol ^a and chloroform ^a	Aliyu <i>et al.</i> , 2011
	antiparasitic (antiplasmodial) and antioxidant	water ^{wp}	Builders <i>et al.</i> , 2011
<i>V. amygdalina</i>	antibacterial	water ^r and ethanolic ^l	Ogbulie <i>et al.</i> , 2007
	bactericidal (oral bacterial)	cold water ^{s, b, p}	Rotimi and Mosadomi, 1987
	antifungal	water ^{sb, r} and methanol ^{sb, r}	Nduagu <i>et al.</i> , 2008
	antiviral	ethanol ^{tr}	Vlietinck <i>et al.</i> , 1995
	antiparasitic (antiamoebic)	methanol ^l and water ^l	Moundipa <i>et al.</i> , 2005
	(antileishmanial)	chloroform ^l and ethanol ^l	Carvalho and Ferreira 2001
	(antischistomiasis)	petroleum ether ^l and ethanolic ^l	Adedapo <i>et al.</i> , 2007
	(antihelmintic)	water ^{l, s, r}	Adedapo <i>et al.</i> , 2007
	(antiplasmodial)	ethanolic ^{l, r}	Abosi and Raseroka, 2003
	analgesic and antipyretic	water ^l and ethanol ^r	Tekobo <i>et al.</i> , 2002
	anti-inflammatory	water ^l	Iroanya <i>et al.</i> , 2010
	antioxidant	ethanol ^r and methanol ^{ns}	Yeap <i>et al.</i> , 2010
	cytotoxic	cold water ^{wp}	Vlietinck <i>et al.</i> , 1995
	anticancer	cold water ^l	Izevbigie <i>et al.</i> , 2003
	antidiabetic	water ^{wp} and isopropanol ^{wp}	Erasto <i>et al.</i> , 2006 Taiwo <i>et al.</i> , 2009
	liver protective	methanol ^l and water ^l	Adesanoye and Farombi, 2009

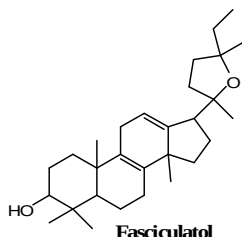
	pesticidal and insecticidal	methanol ^l	Ohigashi <i>et al.</i> , 1991
<i>V. antihelmintica</i>	antibacterial	water ^{ns} -ethanolic ^{ns}	Parekh and Chanda 2008
	anti-arthritic	ethanolic ^{sd}	Otari <i>et al.</i> , 2010
	anti-inflammatory	water ^{ns} -ethanolic ^{ns}	Parekh and Chanda 2008
	antidiabetic and antihyperglycemic	EtOAc:isopropanol (1:1) ^{sd}	Fatima <i>et al.</i> , 2010
<i>V. auriculifera</i>	Antibacterial and antiviral	Cold water	Muthaura <i>et al.</i> , 2007
<i>V. blumeoides</i>	antibacterial	ethanol ^a and chloroform ^a	Aliyu <i>et al.</i> , 2011
<i>V. branchycalyx</i>	antiparasitic (antileishmanial) (antiplasmodial)	CHCl ₃ :EtOAc(1:1) ^l	Oketch-Rabah <i>et al.</i> , 1998
	(antimalarial)	water ^l	Oketch-Rabah <i>et al.</i> , 1997
<i>V. brasiliiana</i>	(antiplasmodial)	hexane ^l	Alves <i>et al.</i> , 1997
<i>V. cinerea</i>	antibacterial	benzene ^l	Gupta <i>et al.</i> , 2003a; Latha <i>et al.</i> , 2009
	antifungal	methanol ^a	Latha <i>et al.</i> , 2009
	antioxidant	methanol ^a	Kumar <i>et al.</i> , 2009; Latha <i>et al.</i> , 2009
	anti-inflammatory	alcoholic ^{fl}	Latha <i>et al.</i> , 1998
	antipyretic	methanol ^{wp}	Gupta <i>et al.</i> , 2003b
	analgesic and antipyretic	chloroform ^l , methanol ^l and ether ^l	Mazumder <i>et al.</i> , 2003
	immunomodulatory	methanolic ^{ns}	Pratheeshkumar and Kuttan, 2010
<i>V. colorota</i>	antibacterial, antiparasitic (antiplasmodial), antidiabetic and anti-inflammatory	CHCl ₃ -MeOH (9:1) ^l	Chukwujekwu <i>et al.</i> , 2009; Cioffi <i>et al.</i> , 2004
	antidiabetic	aqueous ^l	Sy <i>et al.</i> , 2004
<i>V. condensata</i>	analgesic, antigastitis, antiulcer and antinociceptive	acetone-EtOH-EtOAc ^l	Frutuoso <i>et al.</i> , 1994; Sanogo <i>et al.</i> , 1996; Risso <i>et al.</i> , 2010
<i>V. glabra</i>	antifungal	ns	Gundidza, 1986
<i>V. hymenolepis</i>	tumor inhibitory activity	alcoholic ^l	Kupchan <i>et al.</i> , 1969

<i>V. karaguensis</i>	antibacterial and antileukaemic	Ns	Mungarulire,1993; Taiwo <i>et al.</i> , 1999
<i>V. kotchyana</i>	antibacterial, analgesic, antigastitis and antiulcer	aqueous/ <i>n</i> -butanol ^r extract and acidic ^r	Frutuoso <i>et al.</i> , 1994; Germano <i>et al.</i> , 1996; Sanogo <i>et al.</i> , 1996, 1998
<i>V. oocephala</i>	antibacterial	ethanol/chloroform ^a	Aliyu <i>et al.</i> , 2011
<i>V. paltula</i>	antibacterial, antifungal, anti-inflammatory and antipyretic	ethanolic ^{wp, fl, fr, t, l}	Chiu and Chang 1987
<i>V. polyanthes</i>	antiulcerogenic	methanolic ^a and chloroform ^a	Barbastefano <i>et al.</i> , 2007
<i>V. pogosperma</i>	antibacterial	Ns	Tripathi <i>et al.</i> , 1981
<i>V. scorpioides</i>	cytotoxic effects (anti-tumor)	dichloromethane ^l	Pagno <i>et al.</i> , 2006
	bactericidal and fungicidal	chloroform ^l and hexane ^l	Buskuhl <i>et al.</i> , 2010; Freire <i>et al.</i> , 1996
<i>V. thomsoniana</i>	antibacterial and antileukaemic	Ns	Mungarulire, 1993; Taiwo <i>et al.</i> , 1999

Key: superscripts, a = aerial parts, fr = fruits, fl = flowers l = leaves, ns = not specified, r = roots, s = stems, sb = stem bark, sd = seeds, wp = whole plant

A phytochemical review of the triterpenoids from *Vernonia* species

The isolation of triterpenoids from this genus is recorded to have begun as early as 1979, where the tetracyclic triterpenoid, fasciculatol was isolated from *V. fasciculata*. This remains to be the only tetracyclic triterpenoid isolated from *Vernonia* and all other phytochemical studies have reported pentacyclic triterpenoids.

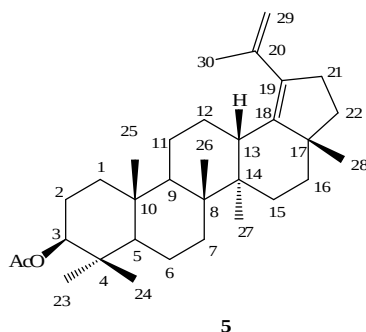
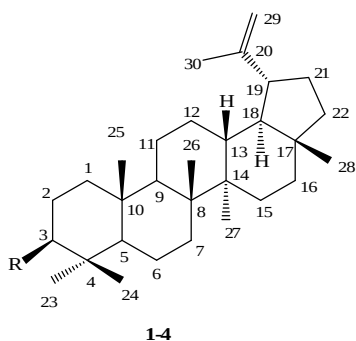


In this review, We focus on triterpenoids from *Vernonia* species. Seven classes of triterpenoids have been isolated and reported in this genus, of which five are closely related and possess five six-membered rings in their basic skeleton (oleanane, ursane, taraxarene, friedelane and

82 friedoursane), the other two classes being lupane (four six membered rings and a five-
 83 membered ring) and a tetracyclic triterpenoid.

84 **Lupane triterpenoids**

85 The lupane triterpenoids are characterised by four six-membered rings with a fifth five-
 86 membered ring to which an isopropyl group is attached. Five lupane triterpenoids have been
 87 isolated from *Vernonia* species, all with the same basic skeleton. All *Vernonia* species except
 88 for *V. cinerea*, *V. fasciculata* and *V. saligna* were found to contain lupeol (1). *V. cinerea* and *V.*
 89 *saligna* although not containing lupeol did contain derivatives of lupeol, lupenyl acetate (2) in
 90 *V. cinerea* and lupeol palmitate (3), a glycoside (4) and an acetate (5) in *V. saligna*.



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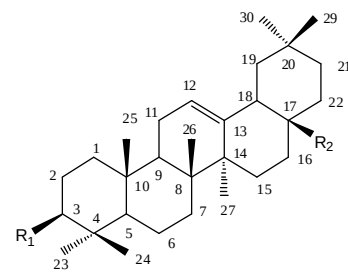
	R
1. Lupeol	OH
2. lupenyl acetate	OAc
3. lupenyl palmitate	OCO(CH ₂) ₁₄ CH ₃
4. lupenyl-20(29)en-3β-O-D-glucoside	O-Glu
5. 18,19-dehydrolupenyl acetate	OAc

92 **Oleanane triterpenoids**

93 Another widely distributed triterpenoid in *Vernonia* is the oleanane triterpenoid, β-amyrin (6),
 94 being found in all *Vernonia* species except *V. arkansana*, *V. chunii*, *V. fasciculata* and *V.*
 95 *potamophila*, however *V. chunii* did contain oleanolic acid (10). *V. mollissima* and *V. patula*

contained β -amyrin acetate (**7**), while *V. saligna* and *V. patula* contained β -amyrin palmitate (**8**) and β -amyrin benzoate (**9**) respectively. The oleanane triterpenoids are characterised by five six-membered rings with a double bond at Δ^{12} and two methyl groups situated on the same carbon at position 20.

		R₁	R₂
6	α -amyrin	OH	CH ₃
7	β -amyrin acetate	OAc	CH ₃
8	α -amyrin palmitate	OCO(CH ₂) ₁₄ CH ₃	CH ₃
9	α -amyrin benzoate	OCOPh	CH ₃
10	oleanolic acid	OH	COOH



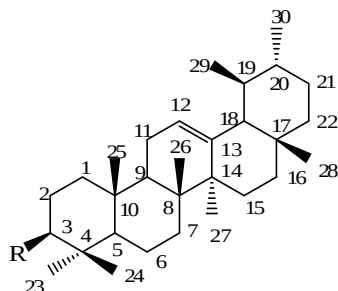
Taraxarane and Ursane triterpenoids

The difference between the oleanane triterpenoids, the taraxarane and ursane triterpenoids lies in the position of the methyl groups on ring E. In the oleananes there are two methyl groups at C-20 whereas in the taraxaranes and the ursanes, a methyl group migrates from the oleanyl cation, resulting in the methyl groups being on adjacent carbon atoms, C-19 and C-20. The ursane, α -amyrin (**11**) is the third most common triterpenoid apart from lupeol (**1**) and β -amyrin (**6**), being found in ten of the sixteen *Vernonia* species studied phytochemically. The three compounds, lupeol (**1**), β -amyrin (**6**) and α -amyrin (**11**) form a suite of compounds found in nine of the sixteen species of *Vernonia* and may be used as a chemotaxonomic marker for the genus.

In addition, α -amyrin acetate (**12**) is found in *V. patula* and together with α -amyrin (**11**) in *V. saligna*. Taraxasterol (**14**) is found together with α -amyrin (**11**) in *V. incana* and *V. cognata*, while *V. chalybaea* contains α -amyrin (**11**), pseudotaraxasteryl acetate (**13**) and taraxasteryl acetate (**15**) and *V. cinerea* contains α -amyrin (**11**), α -amyrin acetate (**12**), 24-hydroxytaraxa-14-ene (**16**), 3 β -acetoxyurs-13(18)-ene (**17**) and 3 β -acetoxyurs-19-ene (**18**).

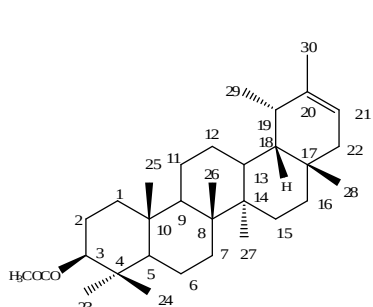
Between the taraxaranes and the ursanes, there is a difference in the position of the double bond, which is brought about by the way in which the taraxasteryl cation is quenched by the

loss of the hydrogen with concomitant hydrogen migrations. In α -amyrin (**11**) and the rest of the ursanes, the H-12 proton is lost and the double bond is formed at Δ^{12} . Acetylation of **11** leads to formation of α -amyrin acetate (**12**).

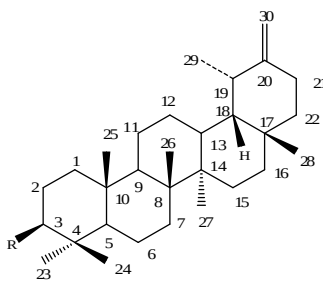


α -amyrin R = OH (**11**)
 α -amyrin acetate R = OAc (**12**)

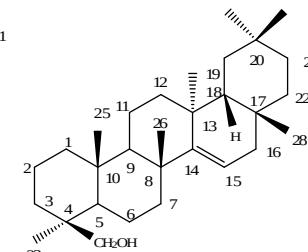
In the taraxaranes, the proton at either C-21 or C-30 is lost, leading to a double bond at either Δ^{20} (**13**) or at 20(30) leading to taraxasterol (**14**) with acetylation of **14** resulting in **15**. It is highly likely that the compound classified as a taraxarene (**16**) does not belong in this class and should be grouped with other compounds with a double bond at Δ^{14} resulting from the loss of a proton at C-15 in the oleanyl cation with hydride migrations quenching the cation.



pseudotaraxasteryl acetate (**13**)

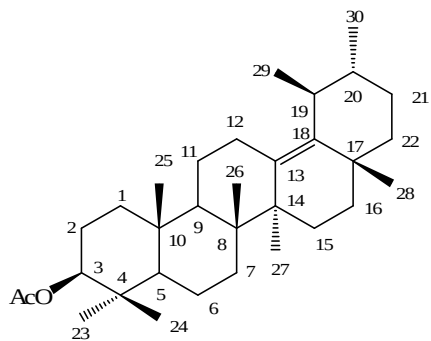


R = OH, taraxasterol (**14**)
R = OAc, taraxasteryl acetate (**15**)

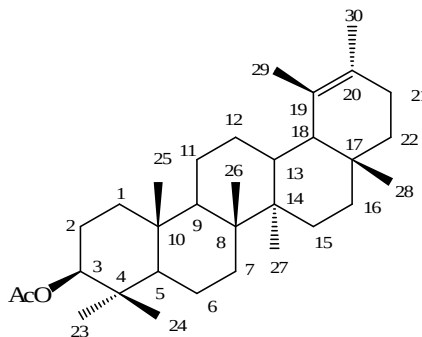


24-hydroxytaraxer-14-ene (**16**)

Compounds **17** and **18** have double bonds in positions different to the ursanes or the taraxaranes, **17** has a double bond between C-13 and C-18 and **18** has a double bond at Δ^{19} and is more likely to be associated with the taraxaranes as the loss of the proton occurs adjacent to the C-20 cation, just as that in **13**.



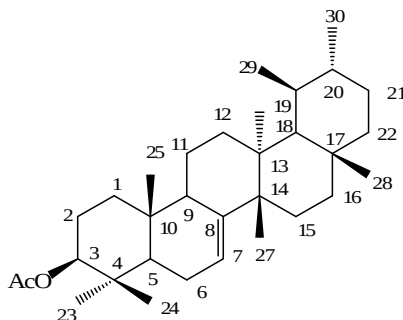
3β-acetoxyurs-13(18)-ene (17)



3β-acetoxyurs-19-ene (18)

Friedoursane triterpenoids

Unlike the cases where the double bond at Δ^{14} and 13(18) were not given their own classification, those with a double bond at the Δ^7 position are classified as friedoursane triterpenoids as in bauerenyl acetate (**19**) isolated from *V. patula*. They come about by loss of a proton at C-7 with methyl and hydrogen shifts quenching the cation in the taraxasteryl cation.

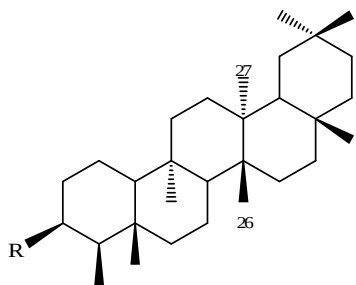


bauerenyl acetate (19)

The Friedelane triterpenoids

The Friedelane triterpenoids, 3β-friedelanol (**20**) and friedelin (**21**) are found in *V. patula* while friedelin (**20**) alone is found in *V. chalybaea* and *V. saligna*. The friedelane triterpenoids are characterised by methyl groups at C-4, C-5, C-9 and C-13, in addition to those at C-14, C-17 and C-20, which differ to the oleanane triterpenoids which have two methyl groups at C-4 and a methyl group at C-10 instead of C-9 and a proton at C-13 instead of the methyl group. This

difference arises from the origin of the methyl migration being from the methyl group at C-4 resulting in a series of methyl and hydrogen migrations to quench the oleanyl cation. Friedelin (21) is brought about by the action of an oxidoreductase oxidising the 3 β -hydroxyl group of 3 β -friedelanol (20) to a ketone (Corsino *et al.*, 2000).



R = OH, 3 β -friedelanol (20)
R = O, Friedlin (21)
R = OCOCH₃, Friedlin acetate (22)

The review revealed that lupeol (1), α -amyrin (6) and α -amyrin (11) were common to several species. *V. paltula* had the highest number of triterpenoids followed by *V. saligna* and *V. chalybaea*. *V. fasciculata* and *V. potamophilia* each had only one triterpenoid from the tetracyclic and lupane class respectively.

V. arkansana

The plant *V. arkansana* is known as Arkansas ironweed two triterpenoids have been isolated from its roots the belonging to the lupane class; lupeol (1) and lupenyl acetate (2) Bohlmann *et al.*, 1981.

V. brasiliiana

Two triterpenoids have been isolated from the leaves of *V. brasiliiana* namely; lupeol (1) and β -amyrin (6) Alves *et al.*, 1997

V. chamaedrys

From the flowers and the stem bark three triterpenoids have been isolated; β -amyrin (6) and α -amyrin (11) form a suite of compounds found in nine of the sixteen species of *Vernonia* and may be used as a chemotaxonomic marker for the genus Catalán *et al.*, 1988.

V. chalybaea

The aerial parts of *V. chalybaea* afforded seven triterpenoids of different classes; lupeol, lupenyl acetate, β -amyrin (**6**) and α -amyrin (**11**), pseudotaraxasteryl acetate, taraxasteryl acetate and friedlin (da Costa *et al.*, 2008).

V. chunii

Lupeol (**1**) and Oleanolic acid (**10**) were isolated from *V. chunii* (Yuan *et al.*, 2008).

V. cinerea

The root bark of *V. cinerea* offered lupenyl acetate (**2**), β -amyrin (**6**) and α -amyrin (**11**), α -amyrin acetate (**12**), 24-hydroxytaraxa-14-ene (**16**), 3 β -acetoxyurs-13(18)-ene (**17**) and 3 β -acetoxyurs-19-ene (**18**) (Misra *et al.*, 1984a, 1984b, 1993).

V. cognata

The fruits and the leaves four triterpenoids were isolated; Lupeol (**1**), β -amyrin (**6**) and α -amyrin (**11**) and taraxasterol (**14**) (Bardon *et al.*, 1988).

V. fasciculata

Fasciculatol is the only reported tetracyclic triterpenoid from *Vernonia* being isolated in *V. fasciculata* and is formed by the oxidation and then cyclisation of the side chain of euphol /tirucallol. Reduction at position 12 leads to the formation of a double bond with the concomitant loss of the methyl group at position 13 (Narain, 1979).

V. incana

The flowers and the leaves offered four triterpenoids; Lupeol, β -amyrin (**6**) and α -amyrin (**11**) and taraxasterol (**14**) (Bardon *et al.*, 1988).

V. mollissima

The aerial parts of *V. mollissima* Lupeol (**1**), β -amyrin (**6**), β -amyrin acetate (**7**) and α -amyrin (**11**) (Catalán and Iglesias, 1986).

V. nitidula

The leaves and flowers yielded; Lupeol (**1**), β -amyrin (**6**), β -amyrin acetate (**7**) and α -amyrin (**11**) (Bardon *et al.*, 1988a).

V. patula

lupeol, lupenyl acetate (2) in *V. cinerea* and lupeol palmitate (3), β -amyrin (6), β -amyrin acetate (7), β -amyrin benzoate (9), α -amyrin acetate (12), bauerenyl acetate (19), 3 β -friedelanol (20) and friedelin (21). They were isolated from the whole plant, (Liang and Min, 2003; Liang *et al.*, 2010).

V. potamophilia

The leaves of *V. potamophilia* yielded lupeol (1) (Babady-Bila *et al.*, 2003).

V. saligna

The whole plant yielded lupeol palmitate (3), a glycoside (4) and an acetate (5) α -amyrin (6), α -amyrin palmitate (8), α -amyrin (11), α -amyrin acetate (12), friedelin (21) Huang and Liu, 2004.

V. squamulosa

The aerial parts of the plant *V. squamulosa* gave Lupeol (1), β -amyrin (6) and α -amyrin (11) (Catalán and Iglesias, 1986).

V. tweediana

The aerial parts of the plant *V. tweediana* gave Lupeol (1), β -amyrin (6) and α -amyrin (11) (Zanon *et al.*, 2008).

V. auriculifera

The phytochemical investigation of *V. auriculifera* led to the isolation of seven triterpenoids. Extracts from the leaves were found to contain one lupane-type triterpenoid (lupenyl acetate 2), one ursane-type triterpenoid (α -amyrin 11), two oleanane-type triterpenoids (β -amyrin 6 and β -amyrin acetate 7). The stem bark afforded friedlin/friedelanone (21) and friedelin acetate (22) belonging to the friedelane class. From the roots, oleanolic acid (10), the parent oleanane type triterpene, was isolated (Kiplimo *et al.*, 2011).

CONCLUSION

This review shows that the genus *Vernonia* is rich in species with extensive ethnomedicinal use, especially in Africa, and extracts obtained by various preparation methods are used, especially from the leaves, bark and roots. There are extensive studies of *V. amygdalina* and *V.*

220 *scorpioides* pointing to their use in folk medicine and confirmed by their biological properties,
221 and confirms that the genus is of immense value based on the studies of biology and chemistry
222 of natural products.

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