Secondary metabolites of *Chrysanthemum* genus and their biological activities

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***Chrysanthemum* genus synthesizes and accumulates a variety of secondary metabolites. Some of the biologically active secondary metabolites and pyrethroids are responsible for the insecticidal activity of the well known plant species *Chrysanthemum cinerariaefolium*. The present review summarizes information available on the secondary metabolites isolated from *Chrysanthemum* genus.**

Keywords: Biological activity, chemical composition, *Chrysanthemum*, pyrethroids, secondary metabolites.

CHRYSANTHEMUM is a cosmopolitan genus, comprising about 300 species of herbs and undershrubs, among which a few yield the commercial insecticide known as Pyrethrum. Several species of *Chrysanthemum* are ornamental and grown in gardens for their large, showy, multicoloured flowers[1]. Pyrethrum (*Chrysanthemum cinerariaefolium*) has been under cultivation around the world for nearly 150 years, with Kenya accounting for about 83% of the present world production[2]. In India, it is cultivated on a large scale only in Kashmir, though successful trials of cultivation have been reported at Kullu, Palampur, Mayurbhanj, Kumaun, Assam, Karnataka, Kerala and Kodaikanal[1]. Its flowers yield an important insecticide, i.e. the pyrethrins. The pyrethrin content, being a quantitative character, always poses a problem before the breeders while selecting desired genotypes having high pyrethrin content[3]. The present review deals with compilation of chemical composition and biological activities reported in various *Chrysanthemum* species up to 2004.

Chemical constituents

Search for the concerned active compounds has led to the isolation of several pyrethroids, sesquiterpenoids, flavonoids, coumarins, triterpenoids, steroids, phenolics, purines, lipids, aliphatic compounds and monoterpenoids from different plant parts of *Chrysanthemum*.

The phytochemicals[4–29] isolated from different parts of the plants and their percentages are listed in Tables 1 and 2.

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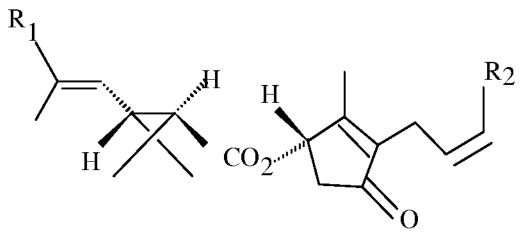
Monoterpenoids

The essential oil constituents (monoterpenoids) reported from various *Chrysanthemum* species are listed[4–9,29] in Table 2.

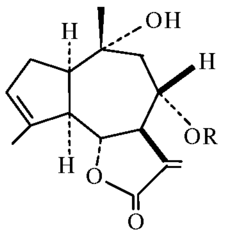
Twelve compounds were identified in the *C. cinerariaefolium* oil by GC and GC-MS. The major compounds of the oil were trans-β-farnesene (41.36%), β-cubebene (17.27%) and δ-nerolidol (14.23%)[8].

Pyrethroids

Pyrethrum extract is one of the most important natural insecticides extracted from Pyrethrum plants. The biologically active constituents of Pyrethrum extract are the pyrethrins, also known as 'rethrins'. Pyrethrins are esters formed by a combination of two acids, chrysanthemic acid and pyrethric



1. $R_1 = CH_3$, $R_2 = CH_3$
2. $R_1 = CO_2CH_3$, $R_2 = CH_3$
3. $R_1 = CH_3$, $R_2 = C_2H_5$
4. $R_1 = CO_2CH_3$, $R_2 = C_2H_5$
5. $R_1 = CH_3$, $R_2 = -CH=CH_2$
6. $R_1 = CO_2CH_3$, $R_2 = -CH=CH_2$



7. R = CO.C (Me) = CH.Me (Angeloyl)
17. R = Ac
19. R = H

Table 1. Compounds isolated from *Chrysanthemum* plants

Compound	Plant part	Plant species	Percentage	Reference
Pyrethroids				
Cinerin I (**1**)	FL	*Chrysanthemum cinerariaefolium*	5.053	10
Cinerin II (**2**)	,,	,,	5.331	10
Jasmolin I (**3**)	,,	,,	2.487	10
Jasmolin II (**4**)	,,	,,	2.408	10
Pyrethrin I (**5**)	,,	,,	19.906	10
Pyrethrin II (**6**)	,,	,,	15.286	10
Sesquiterpene lactones				
Angeloylcumambrin-B (**7**)	EP	*C. oranatum*	0.01	11
	AP	*C. indicum*	0.0055	14
Angeloylajadin (**8**)	AP	*C. indicum*	0.0059	14
Arteglasin-A (**9**)	AP	,,	0.0008	14
Caryolane-1,9-β-diol (**10**)	FL	,,	–	16
Chrysanthediol-A (**11**)	FL	*C. morifolium*	0.00046	15
Chrysanthediacetate-B (**12**)	FL	,,	0.0003	15
Chrysanthediacetate-C (**13**)	FL	,,	0.0004	15
Chrysanolide (**14**)	,,	*C. cinerariaefolium*	0.0015	18
Chrysanin (**15**)	,,	,,	0.0011	18
Clovanediol (**16**)	,,	*C. indicum*	–	16
Cumambrin-A (**17**)	EP	*C. oranatum*	0.05	11
	FLH	*C. coronarium*	–	13
Dihydrocumambrin-A (**18**)	FLH	*C. coronarium*	–	13
Cumambrin-B (**19**)	EP	*C. oranatum*	0.0075	11
Delobanone (**20**)	SFF	*C. indicum*	-	24
β-Dictyopterol (**21**)	FL	*C. morifolium*	0.0016	15
Eupatilin (**22**)	FL	*C. indicum*	–	16
Handelin (**23**)	EP	*C. oranatum*	0.075	11
Indicumenone (**24**)	SFF	*C. indicum*	–	24
Kikkanol-A (**25**)	FL	,,	–	16
Kikkanol-B (**26**)	,,	,,	–	16
Kikkanol-C (**27**)	,,	,,	–	16
Kikkanol-D (**28**)	,,	,,	0.00065	16
Kikkanol-D-monoacetate (**29**)	,,	,,	0.00032	16
Kikkanol-E (**30**)	,,	,,	0.00098	16
Kikkanol-F (**31**)	,,	,,	0.00079	16
Kikkanol-F-monoacetate (**32**)	,,	,,	0.00148	16
Luteolin (**33**)	,,	,,	–	16
Oplopanone (**34**)	,,	,,	–	16
Parthenolide	LF	*C. parthenium*	–	19
Pyrethrosin (**35**)	FLH	*C. cinerariaefolium*	–	17
β-Cyclopyrethrosin (**36**)	FL	*C. cinerariaefolium*	0.034	18
Dihydro-β-cyclopyrethrosin (**37**)	FL	*C. cinerariaefolium*	0.005	18
	FLH	,,	0.0092	12
(+)-Sesamin	FL	,,	0.01	18
cis-spiroketalenolether polyyne (**38**)	FL	*C. indicum*	–	16
trans-spiroketalenolether polyyne (**39**)	FL	*C. indicum*	–	16
Taraxasterol	FL	*C. cinerariaefolium*	0.205	18
	DFL	,,	–	27
Tatridin-A (**40**)	FLH	,,	0.00058	12
Tatridin-B (**41**)	,,	,,	0.00058	12
(11*R*)-11,13-Dihydrotatridin-A (**42**)	,,	,,	0.00208	12
(11*R*)-11,13-Dihydrotatridin-B (**43**)	,,	,,	0.001	12
(11R)-6-O-β-D-Glucosyl-11,13-dihydrotatridin-B (**44**)	,,	,,	0.0058	12
Sterols				
Campesterol and sitosterol	FL, LF, ST, RT	*C. parthenium* var. Aureum var. Schneeball	64.31-80.36* 64.26-80.82*	20
Fucosterol	,,	,,	1.79-8.01* 2.06-8.33*	20
Isofucosterol	,,	,,	0.56-6.12* 1.21-5.24*	20

(*contd…*)

Table 1. (*contd…*)

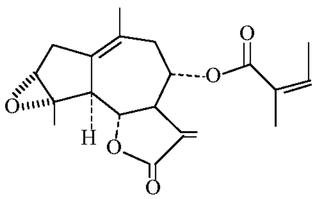
Compound	Plant part	Plant species	Percentage	Reference
Stanols	,,	,,	0.77–1.14* 0.53–2.08*	20
Stigmasterol	,,	,,	14.99–28.00* 14.73–29.16*	20
Flavonoids				
6-Hydroxykaempferol-3,7,4′-trimethylether (tanetin)	LF, FL, SD	*C. parthenium*	–	20
Acacetin-7-O-β-D-galactopyranoside (**45**)	YFL FLH	*C. indicum* *C. morifolium*	0.006 0.0055	21 22
Acacetin-7-O-(6″-rhamnosyl)-β-D-glucopyranoside (**46**)	FLH	*C. morifolium*	0.0015	22
Apigenin (**47**)	FLH	*C. cinerariaefolium*	0.0092	
	FLH	*C. morifolium*	–	
Apigenin-4′-glucuronide (**48**)	DFL	*C. cinerariaefolium*	–	27
Apigenin-7-galacturonic acid methyl ester (**49**)	FLH	*C. cinerariaefolium*	0.0108	12
Apigenin-7-glucuronic acid (**50**)	,,	,,	0.0058	12
Apigenin-7-O-β-D-galactopyranoside (**51**)	FLH	*C. morifolium*	0.0072	22
2″-glucosyl-8-C-glucosyl-4′-*O*-methylapigenin (**52**)	AP	*C. viscidehirtum*	0.0018	23
Apigetrin	,,	,,	0.0015	23
Baicalin (**53**)	FLH	*C. morifolium*	0.0005	22
(+)-Catechin (**54**)	,,	,,	–	22
Chrysin (**55**)	,,	,,	–	22
Fisetin (**56**)	,,	,,	–	22
Flavone (**57**)	,,	,,	–	22
3-hydroxyflavone (**58**)	,,	,,	–	22
Flavanone (**59**)	,,	,,	–	22
7,8-dihydroxyflavanone (**60**)	,,	,,	–	22
4′,5,7-trihydroxylflavanone (**61**)	,,	,,	–	22
Galangin (**62**)	,,	,,	–	22
Hesperidin (**63**)	,,	,,	–	22
Jaceidin (**64**)	FLH	*C. cinerariaefolium*	0.0017	12
Luteolin (**65**)	FLH	*C. cinerariaefolium*	0.0042	12
	FLH	*C. morifolium*	0.021	22
	DFL	*C. cinerariaefolium*	–	27
Luteolin-7-O-β-D-glucopyranoside (**66**)	FLH	*C. morifolium*	0.014	22
Morin (**67**)	,,	,,	–	22
Myricetin (**68**)	,,	,,	–	22
Quercetin (**69**)	,,	,,	0.0072	22
Vitexin	AP	*C. viscidehirtum*	0.0008	23
Miscellaneous fatty acids				
Arachidic	FL	*C. cinerariaefolium*	0.07, 0.34	26
Behenic	,,	,,	0.37	26
Heneicosanoic	,,	,,	0.04	26
Heptadecanoic	,,	,,	0.12,0.02	26
Heptacosanoic	,,	,,	0.02	26
Hexacosanoic	,,	,,	0.15	26
Linoleic	,,	,,	6.62	26
Linolenic	,,	,,	2.94	26
Lignoceric	,,	,,	0.36	26
Myristic	,,	,,	0.25	26
Nonadecanoic	,,	,,	0.05, 0.01, 0.03	26
Nonacosanoic	,,	,,	<0.01	26
Oleic	,,	,,	2.09	26
Octacosanoic	,,	,,	0.07	26
Palmitic	,,	,,	0.04, 0.01, 4.64	26
Pentadecanoic	,,	,,	0.02, < 0.01	26
Pentacosanoic	,,	,,	0.05	26
Stearic	,,	,,	0.04, 1.71	26
Tricosanoic	,,	,,	0.07	26
Triacontanoic	,,	,,	0.02	26

(*contd…*)

Table 1. (*contd...*)

Compound	Plant part	Plant species	Percentage	Reference
Quinic acid				
3,5-dicaffeoyl-4-succinylquinic acid	LF, ST	*C. coronarium*	0.023	25
3,5-dicaffeoylquinic acid	,,	,,	0.0388	25
Polyacetylenic compounds				
1,7(c)-hexadecadien-10,12,14-triyne	FLH	*C. leucanthemum*	0.034	28
1,8(c)-heptadecadien-11,13,15-triyne	,,	,,	0.013	28
4(c)-tridecen-7,9,11-triyn-1-ol-	,,	,,	0.0086	28
1,8(t)-hexadecadien-10,12,14-triyn-(6,7)-oxirane	,,	,,	0.00014	28
[3(t),5(t)-tridecadien-7,9,11-triyn-1-yl]-3-methyl-2-butenoate	,,	,,	0.00028	28

FL, Flower; EP, Entire plant; AP, Aerial parts; FLH, Flower heads; SFF, Small flower form; LF, Leaves; ST, Stem; RT, Root; SD, Seed; YFL, Yellow flowers; DFL, Dried flowers.
Numbers within brackets indicate structure numbers.
*Range of percentage denotes results of various samples of two varieties of *Chrysanthemum* analysed.



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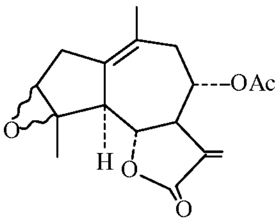

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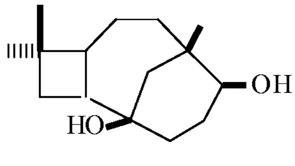

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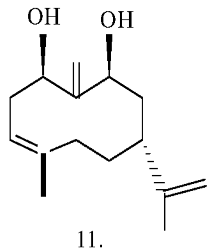

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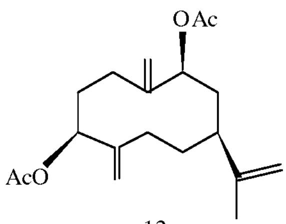

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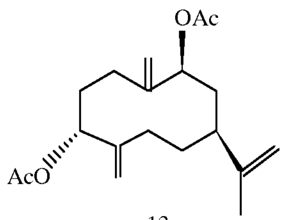

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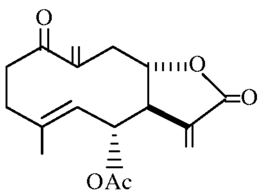

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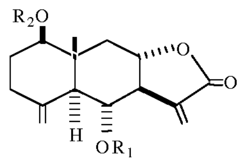

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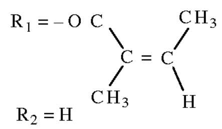
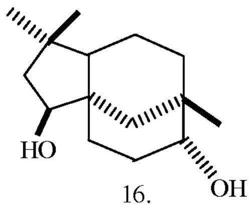


37. R 1 = Ac, R 2 = H



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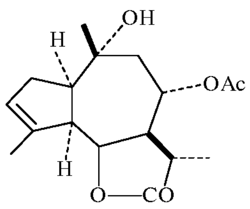

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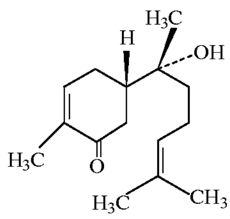

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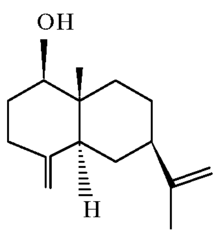

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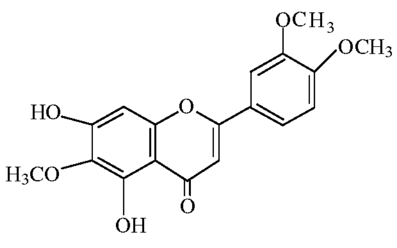

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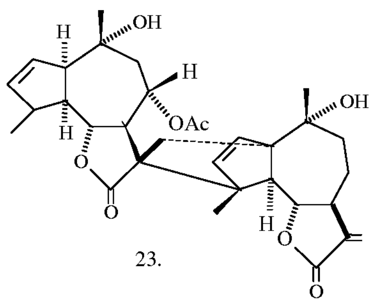

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Table 2. Compounds isolated from essential oil of *Chrysanthemum* plants

Compound	Plant	Percentage	Compound type	Reference
Δ^3-Carene	*Chrysanthemum indicum* (DFL, DLF, AP)	0.2, 0.2, 0.8	Monoterpene	6
	C. viscidehirtum	0.9		9
(E)-β-Farnesene	*Chrysanthemum* cultivars*	1.5, 8.7, 5.5	Sesquiterpene	7
	C. cinerariaefolium	41.36		8
	C. coronarium	8.4		29
(Z),(E)-α-Farnesene	*Chrysanthemum* cultivars*	14.0, 9.0, –	,,	7
(Z)-3-Hexen-1-ol	*Chrysanthemum* cultivars*	1.0, 2.1, –	Alcohol	7
(Z)-3-Hexen-1-ol-acetate	*Chrysanthemum* cultivars*	54.6, 18.9, 32.8	Ester	7
1,8-Cineole	*C. japonense*	4.8	Monoterpene	4
	C. indicum	6.0		5
	C. yoshinaganthum	6.8		5
	C. cuneifolium	23.0		5
	C. indicum (DFL, DLF, AP)	–		6
1-Nonene	*Chrysanthemum* cultivars*	–, –, 1.6	Alkene	7
1-Octen-3-ol	*C. indicum*	–	Alcohol	5
	C. yoshinaganthum	0.1		5
	C. cuneifolium	0.3		5
1-Octen-3-ol-acetate	*Chrysanthemum* cultivars*	–, 1.1, –	Ester	7
1-Octene	*Chrysanthemum* cultivars*	0.3, 0.1, –	Alkene	7
2-Methyl-6-methylene-1,7-octadien-3-one	*Chrysanthemum* cultivars*	–, 0.5, –	Ketone	7
2-Nonanone	*Chrysanthemum* cultivars*	–, 0.3, –	Ketone	7
3-cyclohexen-1-ol-acetate	*Chrysanthemum* cultivars*	–, –, 0.4	Ester	7
3-Hexenyl-2-methylbutanoate	*Chrysanthemum* cultivars*	–, 0.2, –	Ester	7
3-Hexenyl-3-methylbutanoate	*Chrysanthemum* cultivars*	0.3, 0.6, 0.6	Ester	7
3-Octanone	*Chrysanthemum* cultivars*	- , 9.8 , -	Ketone	7
ar-Curcumene	*C. indicum*	1.0	Sesquiterpene	5
	C. yoshinaganthum	–		5
	C. cuneifolium	–		5
Borneol	*Chrysanthemum japonense*	1.5	Monoterpene	4
	C. indicum	3.0		5
	C. yoshinaganthum	–		5
	C. cuneifolium	2.5		5
	Chrysanthemum cultivars*	–, 1.0, –		7
Borneol acetate	*Chrysanthemum* cultivars*	0.1, 1.6, 0.3	Monoterpene	7
Bornyl acetate	*C. japonense*	4.3	Monoterpene	4
	C. indicum	7.5		5
	C. yoshinaganthum	–		5
	C. cuneifolium	1.1		5
	C. indicum (DFL, DLF, AP)	6.3, 0.6, 7.8		6
Cadinol	*C. cinerariaefolium*	0.785	Sesquiterpene	8
Calacolene	*C. indicum*	3.9	,,	5
	C. yoshinaganthum	–		5
	C. cuneifolium	–		5
Calamenene	*C. viscidehirtum*	0.3	,,	9
	C. indicum	0.6		5
	C. yoshinaganthum	–		5
	C. cuneifolium	–		5
Camphene	*C. japonense*	2.3	Monoterpene	4
	C. indicum	2.0		5
	C. yoshinaganthum	Trace		5
	C. cuneifolium	2.2		5
	C. indicum (DFL, DLF, AP)	3.3, 3.6, 8.2		6
	Chrysanthemum cultivars*	0.2, 0.3, –		7
Camphor	*C. japonense*	60.0	,,	4
	C. indicum	0.6		5
	C. yoshinaganthum	Trace		5
	C. cuneifolium	14.7		5
	Chrysanthemum cultivars*	0.9, 0.8, –		7
Carane-4-ol	*C. indicum* (DFL, DLF, AP)	0.7, 0.3, 0.1	,,	6
Carveol acetate	*Chrysanthemum* cultivars*	–, trace, –	Monoterpene	7

Contd...

Table 2. (*contd...*)

Compound	Plant	Percentage	Compound type	Reference
Carvone	*Chrysanthemum* cultivars*	–, 0.2, –	,,	7
Caryophyllene	*C. indicum* (DFL, DLF, AP)	0.4, 3.4, 3.7	Sesquiterpene	6
Caryophyllene oxide	*C. indicum*	3.8	,,	5
	C. yoshinaganthum	1.5		5
	C. cuneifolium	2.5		5
	C. viscidehirtum	2.4		9
Chrysanthenone	*C. japonense*	2.4	Monoterpene	4
	C. indicum	1.6		5
	C. yoshinaganthum	–		5
	C. cuneifolium	–		5
	C. indicum (DFL, DLF, AP)	5.2, 0.5, 5.9		6
Cinnamaldehyde	*C. viscidehirtum*	0.7	Aromatic	9
cis-Chrysanthenyl acetate	*C. japonense*	0.8	Monoterpene	4
cis-Carveyl acetate	*C. japonense*	0.1	,,	4
Citronellyl acetate	*C. viscidehirtum*	0.6	,,	9
Germacrene D	*C. japonense*	6.7	Sesquiterpene	4
	C. indicum	8.5		5
	C. yoshinaganthum	10.6		5
	C. cuneifolium	7.7		5
	C. cinerariaefilium	Trace		8
β-Elemene	*Chrysanthemum* cultivars*	–, Trace, –	Sesquiterpene	7
	C. japonense	1.0		4
	C. indicum	0.4		5
	C. yoshinaganthum	0.8		5
	C. cuneifolium	0.6		5
	C. viscidehirtum	2.4		9
Estafiatin	*C. indicum*	–	,,	5
	C. yoshinaganthum	0.4		5
	C. cuneifolium	–		5
Filifolone	*C. japonense*	0.4	Monoterpene	4
Geraniol	*C. viscidehirtum*	3.1	”	9
Hexyl acetate	*Chrysanthemum* cultivars*	1.5, 2.2, 0.4	Ester	7
Humulene oxide	*C. viscidehirtum*	0.6	Sesquiterpene	9
Isoamyl acetate	*Chrysanthemum* cultivars*	0.2, Trace, –	Ester	7
Isocaryophyllene	*C. cinerariaefolium*	0.71	Sesquiterpene	8
Limonene	*C. indicum*	–	Monoterpene	5
	C. yoshinaganthum	Trace		5
	C. cuneifolium	–		5
	Chrysanthemum cultivars*	0.7, 3.3, 0.3		7
	C. viscidehirtum	21.8		9
Linalol	*C. indicum*	0.7	,,	5
Linalol + thujone	*C. yoshinaganthum*	–		5
	C. cuneifolium	–		5
	C. indicum (DFL, DLF, AP)	1.5, 0.5, 1.2		6
	C. viscidehirtum	1.2		9
Linalyl acetate	*C. indicum*	1.5	,,	5
	C. yoshinaganthum	–		5
	C. cuneifolium	–		5
	C. viscidehirtum	0.6		9
Myrcene	*C. indicum*	6.0	Monoterpene	5
	C. yoshinaganthum	0.2		5
	C. cuneifolium	2.2		5
	C. viscidehirtum	0.8		9
	C. coronarium	31.9		29
Myrtenol	*C. indicum*	–	,,	5
	C. yoshinaganthum	54.8		5
	C. cuneifolium	Trace		5
Myrtenal	*C. indicum*	–	,,	5
	C. yoshinaganthum	0.2		5
	C. cuneifolium	–		5
Nerolidol	*C. indicum*	2.8	Sesquiterpene	5
	C. yoshinaganthum	–		5

Contd...

Table 2. (*contd*...)

Compounds	Plants	Percentage (%)	Compounds type	References
	C. cuneifolium	–		5
Nojigiku alcohol	*C. japonense*	5.4	Monoterpene	4
Octane	*Chrysanthemum* cultivars*	0.1, –, –	Alkane	7
Octenal	*C. viscidehirtum*	0.2	,,	9
o-Cymene Z	*C. viscidehirtum*	0.2	Monoterpene	9
p-Cymene	*C. japonense*	0.4	Monoterpene	4
	C. indicum	0.9		5
	C. yoshinaganthum	Trace		5
	C. cuneifolium	Trace		5
	C. indicum (DFL, DLF, AP)	–		6
	Chrysanthemum cultivars*	1.8, 0.7, 0.1		7
	C. viscidehirtum	0.9		9
Pentacosane	*C. indicum* (DFL, DLF, AP)	0.4, Trace, 0.2	Alkane	6
Sabinene	*Chrysanthemum* cultivars*	0.4, 0.3, 2.7	Monoterpene	7
	C. viscidehirtum	3.9		9
Spathulenol	*C. cinerariaefolium*	7.41	Sesquitepene	8
	C. viscidehirtum	1.3		9
T-Cadinol	*C. viscidehirtum*	0.8	Sesquiterpene	9
Terpinen-4-ol	*C. indicum*	–	Monoterpene	5
	C. yoshinaganthum	0.3		5
	C. cuneifolium	2.1		5
	C. viscidehirtum	1.3		9
Terpinolene	*C. indicum* (DFL, DLF, AP)	0.3, 0.3, 0.3	Monoterpene	6
	Chrysanthemum cultivars*	0.2, 0.7, 0.1		7
Thymol	*C. viscidehirtum*	0.3	,,	9
T-Muurolol	*C. japonense*	1.6	Sesquiterpene	4
	C. indicum	5.3		5
	C. yoshinaganthum	–		5
	C. cuneifolium	6.8		5
	C. viscidehirtum	1.4		9
Toluene	*Chrysanthemum* cultivars*	0.7, Trace, 1.9	Aromatic	7
trans-Chrysanthemumic acid	*C. cinerariaefolium*	4.53	Monoterpene	8
trans-Carveyl acetate	*C. japonense*	0.2	,,	4
trans-Chrysanthenyl acetate	*C. japnonense*	1.3	,,	4
trans-Pinocarveol	*C. indicum*	Trace	,,	5
	C. yoshinaganthum	–		5
	C. cuneifolium	0.3		5
Veleranone	*C. indicum*	–	Sesquiterpene	5
	C. yoshinaganthum	–		5
	C. cuneifolium	2.1		5
Zingiberene	*Chrysanthemum* cultivars*	–, –, 4.5	,,	7
α-Bisabolene	*C. indicum* (DFL, DLF, AP)	0.2, –, –	Sesquiterpene	6
α-Cadinol	*C. japonense*	0.1	Sesquiterpene	4
	C. indicum	4.5		5
	C. yoshinaganthum	–		5
	C. cuneifolium	–		5
	C. viscidehitum	1.5		9
α-Copaene	*C. indicum* (DFL, DLF, AP)	–	Sesquiterpene	6
	C. japonense	0.1		4
	C. indicum	0.3		5
	C. yoshinaganthum	Trace		5
	C. cuneifolium	Trace		5
	C. cinerariaefolium	3.04		8
β-Cubebene	*C. cinerariaefolium*	17.27	,,	8
α-Humulene	*C. viscidehirtum*	0.3	,,	9
α-Muurolene	*C. indicum* (DFL, DLF, AP)	0.7, 4.2, 6.1	,,	6
α-Ocimene	*Chrysanthemum* cultivars*	0.2, 1.3, –	Monoterpene	7
α-Phellandrene	*C. indicum* (DFL, DLF, AP)	0.1, –, 0.6	,,	6
α-Pinene	*C. japonense*	1.4	,,	4
	C. indicum (DFL, DLF, AP)	9.0,2.3, 11.4		6
	Chrysanthemum cultivars*	0.1,0.4, 0.4		7
	C. indicum	0.9		5

Contd...

Table 2. (*contd...*)

Compound	Plant	Percentage	Compound type	Reference
	C. yoshinaganthum	1.0		5
	C. cuneifolium	5.7		5
	C. viscidehirtum	0.5		9
α-Selinene	*C. indicum*	8.0	Sesquiterpene	5
	C. yoshinaganthum	–		5
	C. cuneifolium	–		5
α-Terpinene	*C. indicum* (DFL, DLF, AP)	–, 2.7, 5.0	Monoterpene	6
	Chrysanthemum cultivars*	–, 0.3, –		7
α-Terpineol	*C. indicum*	–	,,	5
	C. yoshinaganthum	–		5
	C. cuneifolium	3.0		5
	C. viscidehirtum	0.8		9
α-Thujene	*Chrysanthemum* cultivars*	0.2, –, 0.3	,,	7
α-Thujone	*C. indicum*	1.5	,,	5
	C. yoshinaganthum	–		5
	C. cuneifolium	–		5
β-Cadinene	*C. indicum* (DFL, DLF, AP)	0.2, 0.7, 0.7	Sesquiterpene	6
β-Caryophyllene	*C. japonense*	1.2	,,	4
	Chrysanthemum cultivars*	2.8, 1.3, 4.0		7
β-Caryophyllene oxide	*C. japonense*	1.1	,,	4
β-Cedrene	*C. indicum* (DFL, DLF, AP)	–, 1.6, 5.0	Sesquiterpene	6
β-Farnesene	*C. indicum*	5.0	,,	5
	C. yoshinganthum	1.7		5
	C. cuneifolium	2.6		5
	C. viscidehirtum	25.0		9
β-phenylethylisovalerate	*C. cinerariaefolium*	3.37	Ester	8
β-Humulene	*C. indicum*	Trace	Sesquiterpene	5
	C. yoshinaganthum	Trace		5
	C. cuneifolium	0.2		5
β-Myrcene	*C. indicum* (DFL, DLF, AP)	0.5, 0.3, 3.1	,,	6
	Chrysanthemum cultivars*	8.9, 14.4, 2.9	,,	7
β-Ocimene	*C. indicum* (DFL, DLF, AP)	–, –, 1.4	,,	6
	Chrysanthemum cultivars*	–, 2.6, –	,,	7
β-Pinene	*C. japonense*	0.6	Monoterpene	4
	C. indicum	0.1		5
	C. yoshinaganthum	0.1		5
	C. cuneifolium	0.3		5
	C. indicum (DFL, DLF, AP)	0.4, 1.3, 4.5		6
	Chrysanthemum cultivars*	–, 0.3, 0.4		7
	C. viscidehirtum	0.6		9
β-Selinene	*C. indicum* (DFL, DLF, AP)	0.3, 2.4, 4.4	Sesquiterpene	6
β-Sesquiphellandrene	*Chrysanthemum* cultivars*	3.1, 1.1, –	Sesquiterpene	7
γ-Cadinene	*C. indicum* (DFL, DLF, AP)	0.3, 1.2, 1.4	Sesquiterpene	6
	C. japonense	0.3		4
	C. indicum	5.1		5
	C. yoshinaganthum	–		5
	C. cuneifolium	–		5
γ-Muurolene	*C. indicum* (DFL, DLF, AP)	0.2, –, –	,,	6
γ-Terpinene	*Chrysanthemum* cultivars*	2.4, 0.6, 0.3	Monoterpene	7
	C. viscidehirtum	0.5		9
δ-Cadinene	*C. cinerariaefolium*	4.06	Sesquiterpene	8
	C. viscidehirtum	1.8		9
δ-Nerolidol	*C. cinerariaefolium*	14.23	,,	8
α-Bisabolol	*C. coronarium*	16.5	”	29
(E),(E)-α-Farnesene	*C. coronarium*	11.0	”	29

*Hero, Purple Anne, Surfine.
DFL, Dried flowers; DLF, Dried leaves; AP, Aerial parts.

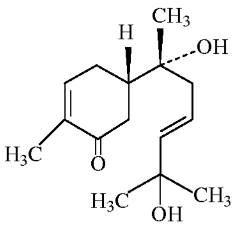
acid, with three alcohols, cinerolone, jasmololone and pyrethrolone. The three esters of chrysanthemic acid (cinerin I, jasmolin I and pyrethrin I) are commonly known as Pyrethrins 1 and the three pyrethric acid esters (cinerin II, jasmolin II and pyrethrin II) are known as Pyrethrins 2 (Table 1). These six compounds with a typical stereochemical configuration are together responsible for the insecticidal activity of the Pyrethrum extract. Pyrethrins are about 1.3 times more toxic than cinerins, and pyrethrin I and cinerin I are nearly four times more effective than pyrethrin II and cinerin II respectively, against houseflies. Pyrethrum extracts that are commercially available in the US usually contain 20 to 50% total pyrethrins. These extracts are commonly used to formulate end-use insecticide products, as well as over-the-counter head-lice control products which are regulated by the Food and Drug Administration[1,10,30].

Biological activity

Biological activities reported for the different species of *Chrysanthemum* plants are molluscicidal, cytotoxicity, antibacterial, inhibitory, pharmacological, toxicity, insecticidal, etc. The various biological activities reported from different extracts of *Chrysanthemum* plants are summarized[9,16,31–47] in Table 3.

Molluscicidal activity

C. cinerariaefolium is known for its insecticidal activity. Molluscicidal activities had previously been noted in the leaves of *C. cinerariaefolium*. Ten average size adult snails were placed in plastic beakers containing 500 ml water (depth 2.54 cm) in which various concentrations of acetone solution of the extract were added. Snails were fed on fresh lettuce leaves. Three replications per test solution were used. All tests were run for 24 h. Death of the snails was checked using WHO methods[31]. The essential oil from *C. viscidehirtum* also showed mild molluscicidal activity against *Bulinus truncatus*.



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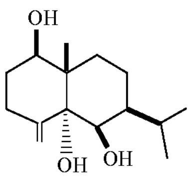

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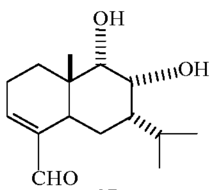

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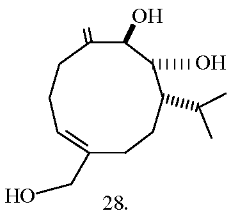

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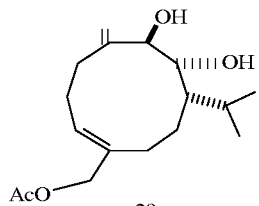

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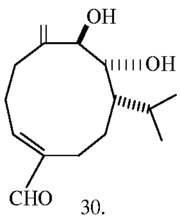

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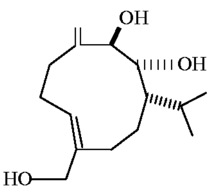

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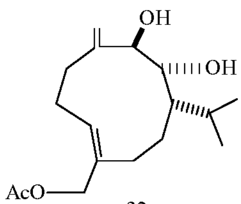

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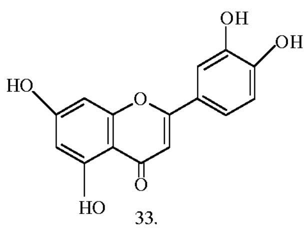

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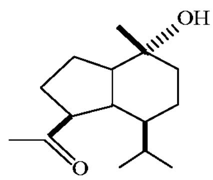

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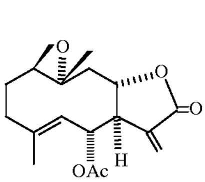

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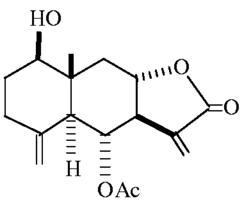

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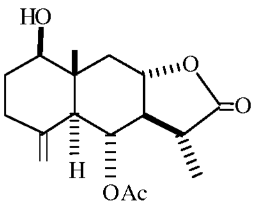

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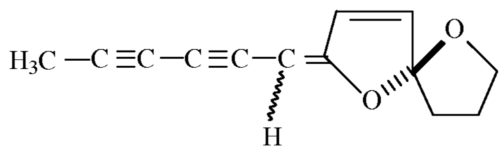

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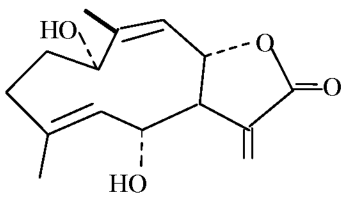

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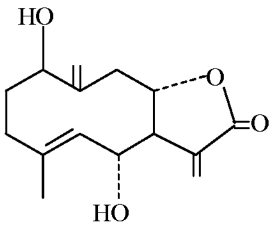

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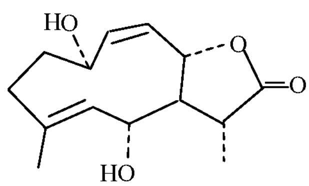

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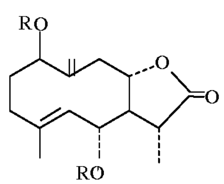


43. R, R' = H
44. R = H, R' = 1- â - D - glucosyl

Table 3. Biological activity for extracts of *Chrysanthemum* plant

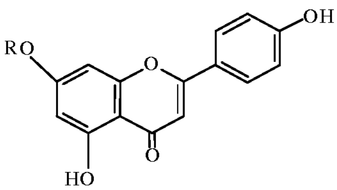
Plant extract	Plant part	Plant species	LC_{50}/IC_{50}	Species	Reference
Molluscicidal activity					
Methanol extract	FLH	*Chrysanthemum cinerariaefolium*	125 ppm	Snails	31
Water extract*	AP	*C. viscidehirtum*	1070 ± 110 ppm	*Bulinus truncatus*	9
Cytotoxicity activity					
EtOH extract	AP	*C. coronarium*	83.3284	*Artemia salina*	32
Petrol – Et_2O extract	AP	*C. coronarium*	38.3772	*Artemia salina*	33
Water extract	EP	*C. sibiricum*	12.5 µg/ml	HL-60 cell	47
			102.4 µg/ml	HepG-2 cell	
Antibacterial activity					
Water extract*	AP	*C. viscidehirtum*	1.25	*Salmonella typhi*	9
Water extract*	AP	*C. viscidehirtum*	1.25	*Proteus mirabilis*	9
Water extract*	AP	*C. boreale*	MIC 1.6 mg/ml	*Staphylococcus aureus*	46
”	”	”	MIC > 12.8 mg/ml	*Staphylococcus epidermidis*	”
”	”	”	MIC 0.8 mg/ml	*Streptococcus pyogenes*	”
”	”	”	MIC 0.8 mg/ml	*Streptococcus mutans*	”
”	”	”	MIC > 12.8 mg/ml	*Enterococcus faecalis*	”
”	”	”	MIC 0.8 mg/ml	*Enterococcus gallinarum*	”
”	”	”	MIC > 12.8 mg/ml	*Salmonella typhimurium*	”
”	”	”	MIC 6.4 mg/ml	*Escherichia coli*	”
”	”	”	MIC 1.6 mg/ml	*E. coli* O157 : H7	”
”	”	”	MIC 1.6 mg/ml	*Enterobacter cloacae*	”
”	”	”	MIC > 12.8 mg/ml	*Klebsiella pneumoniae*	”
”	”	”	MIC > 12.8 mg/ml	*Pseudomonas aeruginosa*	”
”	”	”	MIC 0.8 mg/ml	*Vibrio vulnificus*	”
”	”	”	MIC 3.2 mg/ml	*Citrobacter freundii*	”
Antifungal activity					
Water extract*	FL	*C. coronarium*	Inhibition 79.4%	*Alternaria* sp.	45
”	”	”	Inhibition 53.8%	*Alternaria brassicola*	”
”	”	”	Inhibition 82.6%	*Aspergillus flavus*	”
”	”	”	Inhibition 60.1%	*Botrytis cinerea*	”
”	”	”	Inhibition 51.2%	*Fusarium moniliforme*	”
”	”	”	Inhibition 25.9%	*Fusarium solani*	”
”	”	”	Inhibition 21.4%	*Penicillium digitatum*	”
”	”	”	Inhibition 95.5%	*Pythium ultimum*	”
”	”	”	Inhibition 38.1%	*Rhizoctonia solani*	”
”	”	”	Inhibition 24.2%	*Sclerotinia sclerotiorum*	”
”	”	”	Inhibition 74.6%	*Serpula lacrymans*	”
”	”	”	Inhibition 4.7%	*Mycocentrospora acerina*	”
Nitric oxide production inhibitory activity					
Methanol extract	FL	*C. indicum*	89.2 µg/ml	LPS-activated macrophages	16
Ethyl acetate soluble portion	FL	”	17.3 µg/ml	”	16
1-Butanol soluble portion	FL	”	> 300 µg/ml	”	16
Water soluble portion	FL	”	> 300 µg/ml	”	16
Methanol extract	FL	”	3.5 µg/ml	Rat lens aldose reductase	33
Methanol extract	FL	*C. morifolium*	2.6 µg/ml	”	33
Pharmacological activity					
Aqueous extract	LF, ST	*C. indicum*	282.2 ± 5.2 mg/kg	Mice	34
Rat lens aldose reductase inhibitory activity					
Methanol extract	FL	*C. boreale*	5×10^{-7} M	Rat	35
Toxicity activity					
Dilute solution and oleoresin	FL	*C. cinerariaefolium*	> 1500 mg/kg	White rat	36
Oleoresin	FL	”	820 mg/kg	”	37
Purified concentrate	FL	”	1870 mg/kg	”	37
82% concentrate (oral)	FL	”	> 2600 mg/kg	”	38
86.2% concentrate (subcutaneous)	FL	”	> 1600 mg/kg	”	38
20% concentrate	FL	”	100–300 mg/kg	”	39
Partially dewaxed oleoresin	FL	”	794 mg/kg	”	40

Contd...

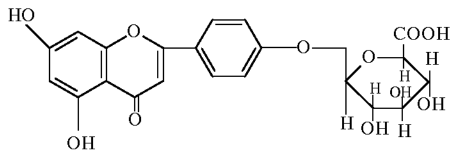
Table 3. (*Contd...*)

Plant extract	Plant part	Plant species	LC_{50}/IC_{50}	Species	Reference
Pale extract	FL	”	584 mg/kg	”	40
Oleoresin	FL	”	634 mg/kg	”	40
77.8% concentrate	FL	”	715–900 mg/kg	”	40
Commercial concentrate	FL	”	480 mg/kg	”	41
20% concentrate	FL	”	1440 mg/kg	”	42
Pyrethrin I	FL	”	260–420 mg/kg	”	43
Pyrethrin II	FL	”	>600 mg/kg	”	43
74% concentrate (oral route)	FL	”	470 mg/kg	”	**
74% concentrate (oral route)	FL	”	>1400 mg/kg	”	44

FLH, Flower heads; AP, Aerial parts; FL, Flowers; LPS, Lipopolysaccharide; LF, Leaves; ST, Stem; EP, Entire plant. *Hydro distillate.
**T. B. Gaines and R. D. Kimbrough (pers. commun., 1972).



47. R = H
49. R = 7- Me-galacturonosyl
50. R = glucuronosyl



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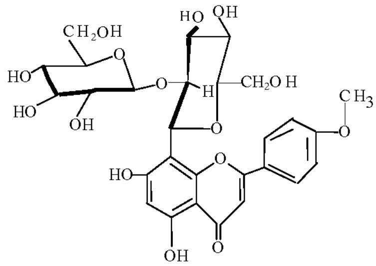

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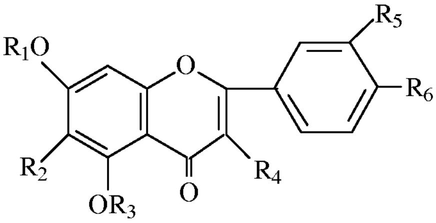


45. R_1 = gal, R_2 = H, R_3 = H, R_4 = H, R_5 = H, R_6 = OMe

46. R_1 = rha1 - 6 glu, R_2 = H, R_3 = H, R_4 = H, R_5 = H, R_6 = OMe

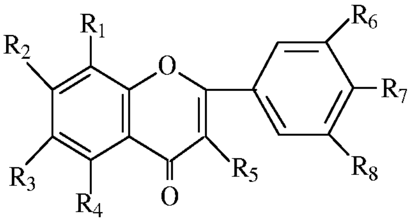
51. R_1 = gal, R_2 = H, R_3 = H, R_4 = H, R_5 = H, R_6 = OH

53. R_1 = glucosiduronyl, R_2 = OH, R_3 = H, R_4 = H, R_5 = H, R_6 = H

65. R_1 = H, R_2 = H, R_3 = H, R_4 = H, R_5 = OH, R_6 = OH

66. R_1 = glu, R_2 = H, R_3 = H, R_4 = H, R_5 = OH, R_6 = OH

69. R_1 = H, R_2= H, R_3 = H, R_4 = OH, R_5 = OH, R_6 = OH



55. R_1 = H, R_2 = OH, R_3 = H, R_4 = OH, R_5 = H, R_6 = H, R_7 = H, R_8 = H

56. R_1 = H, R_2 = H, R_3 = OH,R_4 = H, R_5 = OH, R_6 = H, R_7 = OH, R_8 = H

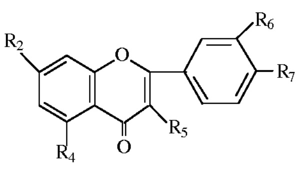
57. R_1 = H, R_2 = H, R_3 = H, R_4 = H, R_5 = H, R_6 = H, R_7 = H, R_8 = H

58. R_1 = H, R_2 = H, R_3 = H, R_4 = H, R_5 = OH, R_6 = H, R_7 = H, R_8 = H

60. R_1 = OH, R_2 = OH, R_3 = H, R_4 = H, R_5 = H, R_6 = H, R_7 = H, R_8 = H

67. R_1 = OH, R_2 = H, R_3 = OH, R_4 = H, R_5 = OH, R_6 = OH, R_7 = H, R_8 = OH

68. R_1 = H, R_2 = OH, R_3 = H, R_4 = OH, R_5 = OH, R_6 = OH, R_7 = OH, R_8 = OH



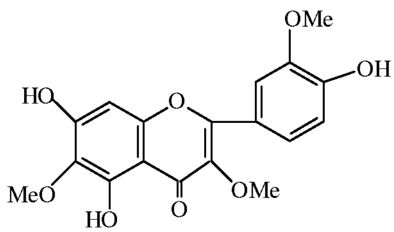
54. R_2 = OH, R_4 = OH, R_5 = OH, R_6 = OH, R_7 = OH

59. R_2 = H, R_4 = H, R_5 = H, R_6 = H, R_7 = H

61. R_2 = OH, R_4 = OH, R_5 = H, R_6 = H, R_7 = OH

62. R_2 = OH, R_4 = OH, R_5 = OH, R_6 = H, R_7 = H

63. R_2 = rha1- 6glu, R_4 = OH, R_5 = H, R_6 = OH, R_7 = OMe



64.

Cytotoxicity

C. coronarium extracts showed high cytotoxicity. The most active one appeared to be the petroleum ether–diethyl ether extracts[32]. The essential oil from *C. sibiricum* exhibited cytotoxic properties along with mild antioxidant activity (IC_{50} = 97.2 μg/ml)[47].

Nitric oxide production inhibitory activity

The methanolic extract and ethyl acetate-soluble portion from the flowers of *C. indicum* were found to show inhibitory activity against nitric oxide production in lipopolysaccharide-activated macrophages[16].

Pharmacological activity

Aqueous extract of leaves and stem of *C. indicum* produced a concentration-dependent contraction of the rat duodenum, which was abolished by atropine. Preliminary phytochemical screening revealed the presence of gycosides, flavanoids, tannins and alkaloids in the extract[34].

Toxicity

Carpenter *et al.*[37], made an exhaustive study of the toxicity of pyrethrins and allethrin to rats, rabbits and dogs with inhalation studies, oral and skin exposure. They reported the oral LD_{50} of Pyrethrum oleoresin at 820 mg/kg on male and female Sherman strain white rats, whereas the LD_{50} of the purified 20% pyrethrins extract was 1870 mg/kg. Although the procedures used in the two tests varied a little, the comparison is still valid enough to show greater toxicity of the unpurified oleoresin.

Antibacterial activity

The essential oil of *C. viscidehirtum* exhibited strong activity against *Salmonella typhi* and *Proteus mirabilis*. The activity was investigated by agar dilution method[9]. Also, the essential oil of *C. boreale* exhibited the activity against six Gram +ve bacteria and 8 Gram –ve bacteria. The activity was investigated by broth dilution method[46].

Antifungal activity

The activity of *C. coronarium* was evaluated against 12 fungal species. In agar diffusion plate assay, the growth of *Alternaria* sp., *Aspergillus flavus* and *Pythium ultimum* was highly reduced (> 80%) at the third day[46]. Activity was also shown by essential oil from *C. viscidehirtum* against four fungi at concentration of 150 ppm[48].

Rat lens aldose reductase inhibitory activity

The methanol extract from whole parts of flowers of *C. boreale* was found to exhibit a significant inhibition of rat tens aldose reductase activity *in vitro*. Among the flavonoids isolated from extracts, luteolin was found to be the most potent AR inhibitor[35], with IC_{50} value of 5×10^{-7} M.

Antimutagenic activity

Methanol extract from the flower head of *C. morifolium* showed a suppressive effect on umu gene expression of the SOS response in *Salmonella typhimurium* against the mutagen 2-(2-furyl)-3-(5-nitro-2-furyl) acrylamide. The four compounds, acacetin, apigenin, luteolin and quercetin suppressed 60.2, 75.7, 90.0 and 66.6 % of SOS-inducing activity at a concentration of 0.70 μmol/ml. These compounds were also active against other mutagens[49].

Conclusion

Secondary metabolism in *Chrysanthemum* plants appears to be a resource of many biologically active compounds. Pyrethrin and its derivatives are already being extensively used for insecticidal activity. *In vitro* studies on other active compounds identified in different species of *Chrysanthemum* may give new therapeutic and agricultural products of commercial importance.

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