Review Article

Citrullus colocynthis: A Treasure of Phytochemical, Pharmacological, Pesticidal and Nematicidal Compounds

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Abstract | Food security and sustainiblity in agriculture is greatly devastated by the emergence of phytonematodes triggering huge yield losses worldwide. Traditionally, synthetic chemicals are widely and commonly used to combat nematode pests; however, the chemical poses negative impact on environment and biodiversity which create urgency in development of an alternative biosafe measure to control these pests. In this regards, researchers have focused on the use of phytopesticides which are eco-friendly and easily accessible and degradable in soil as compared to synthetic chemcials. The given information in this review article highlights the importance of *Citrullus colocynthis* L. Schrad as a promising biological and pesticidal agent useful for the treatment of various medicinal ailments as well as reducing different pests that are harmful for the crop yield and emphasize the need to utilize the useful effect of this plant against nematodes. Phytochemistry of the *C. colocynthis* and the secondary metabolites isolated from the plant i.e. alcohols, esters, fatty acids terpenes, flavonoids and steroids are assembled in this article which further provide a basis for a noteworthy nematicidal effect.

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Introduction

In the current scenario, food security is one of the sustainable development goals as more than 800 million people are chronically starving and millions more are at risk globally (FAO, 2013). Sustainable progress in agriculture and attaining food sufficiency is a central agenda in the global world. Yield and quality of crops grown for human consumption and global food security is menaced by the emergence and propagation of crop pests and pathogens especially weeds, pathogens and animal pests. The food production has been facing the distressing actions of numerous pests like viruses, microbes, fungi, nematodes, insects and parasitic plants, which have triggered noteworthy total economic losses of about 50% of agricultural yield per annum, including 14% and 35% losses in storage and field, respectively (Okwute, 2012).

Among other pests, plant-parasitic nematodes mostly mangle the field as concealed enemies and reduce agricultural harvest. Plant parasitic nematodes inflict direct economic losses of around USD 118000 million in a single 5 years on agriculture (Ahmed *et al*., 2015). The different varieties of crops are being infected by different genera of phytonematodes, some of them with significant importance are *Pratylenchus* spp.,

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Tylenchus spp., *Belonolaimus* spp., *Helicotylenchus* spp., *Paratrichodorus* spp., *Tylenchorhynchus* spp., *Criconema* spp., *Meloidogyne* spp., *Heterodera* spp., *Hoplolaimus* spp., *Tylenchulus* spp., *Rotylenchulus* spp., *Xiphinema* spp., (Anwar and VanGundy, 1989; Maqbool and Shahina, 2001).

In order to manage phytonematodes, number of managing approaches is being embraced to eradicate them. The most common approach includes the use of synthetic chemicals which possess great history. Up till now, management of phytonematodes in agriculture has been reliant on the routine usage of nematicides, but after the awareness of negative influence of these chemical nematicides, researchers are exploring different methods to be used as substitute (Hallmann *et al*., 2009; Siddiqui *et al*., 2009). Due to the adverse effect of chemicals on environment, they are being steadily banned or removed from market (Hague and Gowen, 1987; Sabarwal *et al*., 2018). The unreliable outcomes of nematicides, chiefly due to greater biodegradation (Karpouzas *et al*., 2001; Qin *et al*., 2004; Giannakou *et al*., 2005), aggravation of asthma (Raanan *et al*., 2015; Amaral, 2014), imparting a greater threat of developing type 2 diabetes (Azandjeme *et al*., 2013) and impairment in reproductive systems growth (Martin-Reina *et al*., 2017), generates a crucial requisite for unconventional nematode management approaches (Nicolopoulou-Stamati *et al*., 2016). It has become prime concern to search ecologically friendly substitutes to manage plant parasitic nematode populations.

Recently, the research is seriously oriented towards the plant derived products; the extracts derived from plants have been a main interest of researchers to formulate an alternative bio-safe pesticide to replace the conventionally used pesticides (Marrone, 2019). Besides this, phytochemicals are not explored much for their nematicidal properties in spite of the existing urgency for initiation of nematode management measures, which are hardly supported by industry for the development of nematicides (Chitwood, 2002). The number of studies have reported the nematicidal activities of extracts of various plant species against different species of plant parasitic nematodes (Shaukat *et al*., 2003; Ntalli *et al*., 2010a, b; Dos Santos *et al*., 2010; Faizi *et al*., 2011; D'Addabbo *et al*., 2011; Leonetti *et al*., 2011; Caboni *et al*., 2012).

Many investigators have focused their consideration towards the cucurbitaceae family because fruits, seeds and vegetables are customarily utilized in various ayurvedic preparations (Ajuru and Nmom, 2017). In the plant kingdom, cucurbitaceae family is among the finest hereditarily assorted collection of curative plants (Prashant *et al*., 2017; Zaini *et al*., 2011). For the assessment of nematicidal compound, a biologically vital plant *Citrullus colocynthis* is selected as it is the plant of medicinal importance (Meena and Patni, 2008; Aldamegh *et al*., 2013). *C. colocynthis*, a potential and noteworthy for nutraceutical and therapeutic uses, is grown as a wild perennial plant in arid and barren regions of the world including Pakistan (Asyaz *et al*., 2010; Sawaya *et al*., 1983).

Taxonomic account of Citrullus colocynthis (Linnaeus) schrader

- Kingdom– Plantae
- Division– Magnoliphtya
- Class– Magnolipsida
- Order– Cucurbitales
- Family– Cucurbitaceae
- Genus– *Citrullus*
- Species– *colocynthis*

Bitter apple, egusi, desert gourd are some of the common names of *C. colocynthis*, belonging to cucurbitacae family (Figure 1). Geographically, it is distributed in the barren areas of India, West Pakistan, Ceylon, and Arabia in the region westward of Mediterranean region (Jafri, 1966). Around 17 genera and 32 species are reported among which 25 medical plants of genus *Citrullus* are recorded in Pakistan (Nazimuddin and Naqvi, 1984).

Figure 1: *Unripe and riped fruit of C. colocynthis in field.*

Chemical constituents of Citrullus colocynthis

Chemically, the fruit and its various parts possess treasure of compounds with remarkable biological functions and activities. Seeds of *C. colocynthis* are the rich source of edible oil, comprising of 56% and 25% of linoleic acid and oleic acid respectively as major constituents (Sawaya *et al*., 1983). Flavonoids, glucosides, terpenoids and alkaloids are reported as bioactive chemical components in fruit along with variety of curcurbitacins such as A, B, C, D, E, I, J, K, and L and colocynthosides A and B (Hussain *et al*., 2014). Other than these, many compounds belonging to different classes have also been identified from different parts of *C. colocynthis* plants which are listed in Table 1.

Pharmacological properties of Citrullus colocynthis

C. colocynthis was used as an ancient medicine by the ancient Greek and Roman physicians and is used broadly in folk medicine since ancient times (Uma and Sekar, 2014). Many medicinal and pharmacological activities of *C. colocynthis* like laxative, anti-inflammatory, anti-diabetic, palliative, hair growth, promoting, aborticide, and anti-epileptic were recognized in traditional Iranian medicine (Rahimi *et al*., 2012). The pharmocological activities of different parts of *C. colocynthis* are listed in Table 2.

Pesticidal properties of Citrullus colocynthis

C. colocynthis has gained increasing attention and has also emerged as a natural pesticide and its activity against many economically important pest species has been assessed. It has been suggested as influential insecticide in order to protect the ecosystem and improve the quality of public well-being (Niroumand *et al*., 2016). Many studies support the efficacy of *C. colocynthis* along with other plants as powerful insecticides but only few studies showed nematicidal properties of *C. colocynthis* and recommended to evaluate the overall efficacy of these plants in order to save the environment. Table 3 inlists the pesticidal activities of *C. colocynthis* against various insects and phytonematode pests.

Plants possess the valuable paragon of secondary metabolites which play vital part in many medicinal diseases since ancient times which is also being explored for their use in crop protection as Integrated Pest Management practices (Niroumand *et al*., 2016). Customarily, different parts of *C. colcynthis* plant are consumed in the treatment of different ailments; which shows the multidisciplinary action of this plant. This plant has been the area of great interest for researchers in order to establish the medicinal and pesticidal significance of this plant and to discover new bio-active moieties, for which bulk of research is in progress. Plants may provide a prime and importance method in the integrated nematode management (INM) practices as environmental safety and economical as a new alternative to originally chemical nematicides. Botanical nematicides are the source of alternative bio-rational and eco-safe products to toxic synthetic nematicides. Very little work has been done to consider the potential of *C. colocynthis* to manage phytonematodes.

C. colocynthis is a treasure of numerous bioactive compounds ranging from small hydrocarbons to large and complex flavonoids and terpenoids. It is a rich source of amino acids, hydrocarbons, alcohols, esters, fatty acids, flavonoids and terpenoids specially cucurbitacins. Among these compounds, many have been studied for their nematicidal responses against different species of phytonematodes. Esters like methyl stearate and methyl palmitate had been reported to possess potential to reduce root galls and egg masses, inhibit egg hatching and repel larvae and nematodes in soil (Lu *et al*., 2020). Many fatty acids which are one of the major constituents of *C. colocynthis* are already studied for their nematicidal activities. Oleic acid which is the most common fatty acid in nature was found active against *Bursaphelenchus lignicolus* (Tominaga *et al*., 1982); hexadecanoic, lauric, caprylic and myristic acid found effective against the phytonematode, *Meloidogyne incognita* (Ntalli *et al*., 2010c; Zhang *et al*., 2012). Nematicidal activity of linoleic, lauric and myristic acid is also reported against saprophytic nematode *Coenorhabditis elegans* (Gu *et al*., 2005; Stadler *et al*., 1994); lactic acid was also concluded to be an effective ovicidal agent against root-knot nematodes (Lee *et al*., 2014). Besides these, short chained fatty acid like acetic acid is also reported and concluded to be efficient against plant-parasitic species (Favre-Bonvin *et al*., 1991).

Among alcohols, oleyl alcohol and 1-triacontanol, were found active against *Bursaphelenchus lignicolus* and *Meloidogyne incognita*, respectively (Tominaga *et al*., 1982; Nogueira *et al*., 1996). Phenolic compounds like gallic acid and methyl eugenol were found to be nematotoxic against the root-knot nematode, *Meloidogyne incognita* (Seo *et al*., 2013; Li *et al*., 2013). Other than this, Coumaric acid and a flavonoid, quercetin showed promising anthelmintic activity against *Haemonchus contortus*, a nematode parasite of ruminants (Castillo-Mitre *et al*., 2017).

Table 1: *Compounds isolated from different parts of Citrullus colocynthis.*

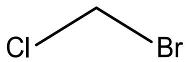
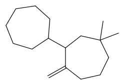
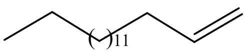
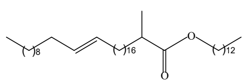
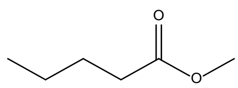
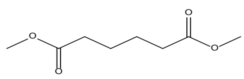
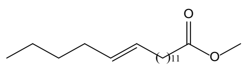
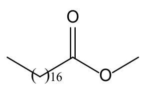
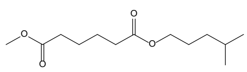
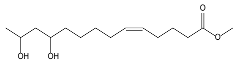
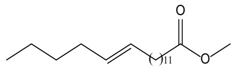
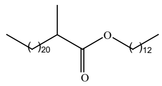
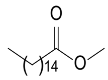
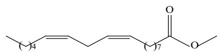
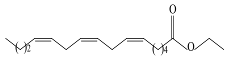
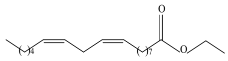
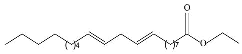
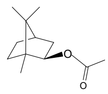
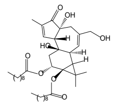
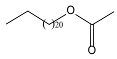
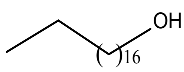
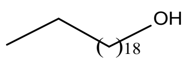
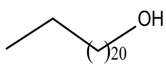
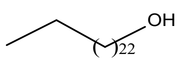
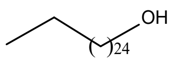
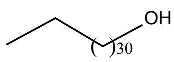
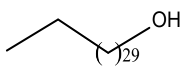
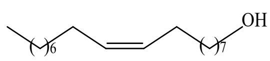
S. No.	Parts	Compound names	Compound structures	Molecular formula and weight	References
	Hydrocarbons				
1.	Fruit Pods	Hentriacontane		$C_{31}H_{64}$ 436	Hatam *et al*., 1990; Selvaraj and Mosses, 2016
2.	Peels	Heptacosane		$C_{27}H_{56}$ 380	Ayoub and Yankov, 1981
3.	Peels	Octacosane		$C_{28}H_{58}$ 453	Ayoub and Yankov, 1981
4.	Peels	Nonacosane		$C_{29}H_{60}$ 408	Ayoub and Yankov, 1981
5.	Peels	Triacontane		$C_{30}H_{62}$ 449	Ayoub and Yankov, 1981
6.	Peels	Dotriacontane		$C_{32}H_{66}$ 450	Ayoub and Yankov, 1981
7.	Peels	Tritriacontane		$C_{33}H_{68}$ 464	Ayoub and Yankov, 1981
8.	Pulp powder	Bromochloro methane		CH_2BrCl 128	Barzegar *et al*., 2017
9.	Pulp powder	Bicyclo heptane, 6, 6dimethyl-2-methylene		$C_{10}H_{16}$ 136	Barzegar *et al*., 2017
10.	Pulp powder	Dodecane		$C_{12}H_{26}$ 170	Barzegar *et al*., 2017
11.	Pulp powder	Hexadecane		$C_{16}H_{34}$ 226	Barzegar *et al*., 2017
12.	Different parts	Hexadecene		$C_{16}H_{32}$ 224	Gupta *et al*., 2018
13.	Different parts	Tetratetracontane		$C_{44}H_{90}$ 619	Gupta *et al*., 2018
	Esters				
14.	Roots	Tridecyl 2 methyl-19-ene-triacontanote		$C_{44}H_{102}O_2$ 643	Manorajani *et al*., 1999
15.	Pulp powder	Methyl valerate		$C_6H_{12}O_2$ 116	Barzegar *et al*., 2017
16.	Pulp powder	Dimethyl hexanedioate		$C_8H_{14}O_4$ 174	Barzegar *et al*., 2017
17.	Pulp powder	Methyl octadec-13-enoate		$C_{19}H_{36}O_2$ 296	Barzegar *et al*., 2017
18.	Pulp powder	Methyl stearate		$C_{19}H_{38}O_2$ 298	Barzegar *et al*., 2017
19.	Pulp powder	1-*O*-methyl 6-*O*-(4-methylpentyl) hexanedioate		$C_{13}H_{24}O_4$ 244	Barzegar *et al*., 2017

Table continues on next page.............

S. No.	Parts	Compound names	Compound structures	Molecular formula and weight	References
20.	Pulp powder	Methyl (*Z*)-11,13-dihydroxytetradec-5-enoate		$C_{15}H_{26}O_4$ 270	Barzegar *et al*., 2017
21.	Fruit	trans-Methyl-13-octadecenoate		$C_{19}H_{36}O_2$ 296	Kumar *et al*., 2019
22.	Roots	Heptadecyl Trieicosanoate		$C_{24}H_{48}O_2$ 368	Manorajani *et al*., 1999
23.	Pods	Methyl Palmitate		$C_{17}H_{34}O_2$ 270	Selvaraj and Mosses, 2016
24.	Pods	Methyl linoleate		$C_{19}H_{34}O_2$ 294	Selvaraj and Mosses, 2016
25.	Pods	Ethyl 6,9,12- Hexadecanoate		$C_{18}H_{30}O_2$ 278	Selvaraj and Mosses, 2016
26.	Pods	Ethyl linoleate		$C_{20}H_{34}O_2$ 306	Selvaraj and Mosses, 2016
27.	Pods	Ethyl 9,12-Octadeca dienoate		$C_{20}H_{36}O_2$ 308	Selvaraj and Mosses, 2016
28.	Pods	Isobornyl Acetate		$C_{12}H_{20}O_2$ 196	Selvaraj and Mosses, 2016
29.	Pods	Phorbol 12,13- Didecanoate		$C_{40}H_6O_8$ 672	Selvaraj and Mosses, 2016
30.	Peels	Docosanyl Acetate		$C_{24}H_{48}O_2$ 368	Ayoub and Yankov, 1981
	Alcohols				
31.	Roots	Nonaeicosanol		$C_{29}H_{60}O$ 424	Manorajani *et al*., 1999
32.	Peels	Hexadecanol		$C_{16}H_{34}O$ 242	Ayoub and Yankov, 1981
33.	Peels	Octadecanol		$C_{18}H_{38}O$ 270	Ayoub and Yankov, 1981
34.	Peels	Eicosanol		$C_{20}C_{42}O$ 298	Ayoub and Yankov, 1981
35.	Peels	Docosanol		$C_{22}H_{46}O$ 326	Ayoub and Yankov, 1981
36.	Peels	Tetracosanol		$C_{24}H_{50}O$ 354	Ayoub and Yankov, 1981
37.	Peels	Hexacosanol		$C_{26}H_{54}O$ 382	Ayoub and Yankov, 1981
38.	Roots	Dotriacontanol		$C_{32}H_{66}O$ 466	Manorajani *et al*., 1999
39.	Roots	1-Hentriacontanol		$C_{31}H_{64}O$ 452	Manorajani *et al*., 1999
40.	Leaves	Oleyl Alcohol		$C_{18}H_{36}O$ 268	Selvaraj and Mosses, 2016

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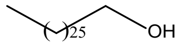
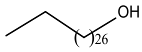
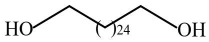
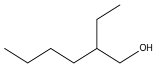
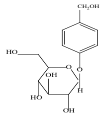
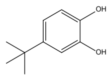
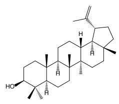
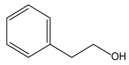
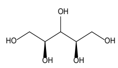
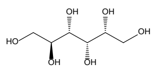
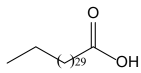
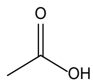
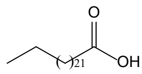
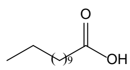
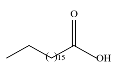
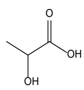
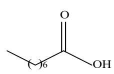
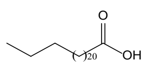
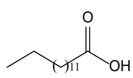
S. No.	Parts	Compound names	Compound structures	Molecular formula and weight	References
41.	Fruits	Heptacosan-1-Ol		$C_{27}H_{56}O$ 396	El Khadem *et al*., 1965
42.	Fruit	N-Octacosanol		$C_{28}H_{58}O$ 410	Hatam *et al*., 1990
43.	Fruit	1, 26-Hexacosan-diol		$C_{26}H_{54}O_2$ 398	Hatam *et al*., 1990
44.	Pulp powder	2-Ethyl-1-hexanol		$C_8H_{18}O$ 130	Barzegar *et al*., 2017
45.	Fruit	4-(B-D-glucopyrano syloxy) benzyl alcohol		$C_{13}H_{18}O_8$ 302	Yoshikawa *et al.,* 2007
46.	Pods	4- (1,1-Dimethylethyl)-1,2-benzenediol		$C_{10}H_{14}O_2$ 166	Selvaraj and Mosses, 2016
47.	Pods	Lupeol		$C_{30}H_{52}O$ 428	Selvaraj and Mosses, 2016
48.	Peels	2-Phenylethanol		$C_8H_{10}O$ 122	Ayoub and Yankov, 1981
49.	Different parts	Xylitol		$C_5H_{12}O_5$ 152	Gupta *et al*., 2018
50.	Different parts	Glucitol		$C_6H_{14}O_6$ 182	Gupta *et al*., 2018
51.	Different parts	Triacontanol		$C_{30}H_{62}O$ 438	Gupta *et al*., 2018
	Fatty acids				
52.	Roots	Dotriacontanoic acid		$C_{32}H_{64}O_2$ 480	Manorajani *et al*., 1999
53.	Pulp powder	Acetic acid		$C_2H_4O_2$ 60	Barzegar *et al*., 2017
54.	Roots	Tetraeicosanoic acid		$C_{24}H_{48}O_2$ 368	Manorajani *et al*., 1999
55.	Seeds Peels	Lauric acid		$C_{12}H_{24}O_2$ 200	Ayoub and Yankov, 1981
56.	Seeds Peels	Stearic acid		$C_{18}H_{36}O_2$ 284	Gurudeeban *et al*., 2010a; Ayoub and Yankov, 1981
57.	Different parts	Lactic acid		$C_3H_6O_3$ 90	Gupta *et al*., 2018
58.	Different parts	Caprylic acid		$C_8H_{16}O_2$ 144	Gupta *et al*., 2018
59.	Different parts	Lignoceric acid		$C_{24}H_{48}O_2$ 368	Gupta *et al*., 2018
60.	Seeds Peels	Myristic acid or Tetradecenoic acid		$C_{14}H_{28}O_2$ 228.	Gurudeeban *et al*., 2010a; Ayoub and Yankov, 1981

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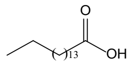
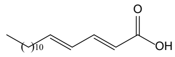
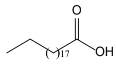
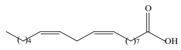
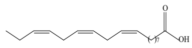
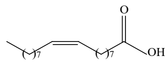
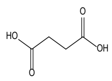
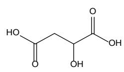
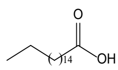
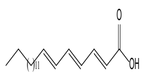
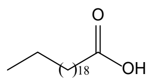
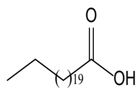
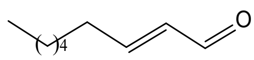
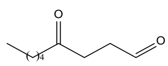
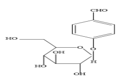
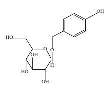
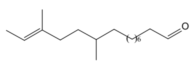
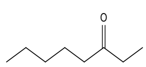
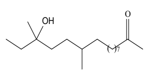
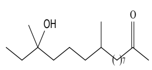
S. No.	Parts	Compound names	Compound structures	Molecular formula and weight	References
61.	Roots Seeds Peels	Hexadecanoic acid		$C_{16}H_{32}O_2$ 256	Hsouna and Alayed, 2012; Sawaya *et al*., 1983; Sadou *et al*., 2007; Sebbagh *et al*., 2009; Ayoub and Yankov, 1981
62.	Seeds	Hexadecadienoic acid		$C_{16}H_{28}O_2$ 252	Yankov and Hussein, 1975a
63.	Peels	Arachidic acid		$C_{20}H_{40}O_2$	Ayoub and Yankov, 1981
64.	Seeds Peels	Linoleic acid		$C_{18}H_{32}O_2$ 280	Gurudeeban *et al*., 2010a; Ayoub *et al*., 1981
65.	Seeds	Linolenic acid		$C_{18}H_{30}O_2$ 278	Gurudeeban *et al*., 2010a
66.	Seeds Peels	Oleic acid		$C_{18}H_{34}O_2$ 282	Gurudeeban *et al*., 2010a; Ayoub and Yankov, 1981
67.	Different parts	Succinic acid		$C_4H_6O_4$ 118	Gupta *et al*., 2018
68.	Different parts	Malic acid		$C_4H_6O_5$ 134	Gupta *et al*., 2018
69.	Different parts	Margaric acid		$C_{17}H_{34}O_2$ 270	Gupta *et al*., 2018
70.	Different parts	Eicosatrienoic acid		$C_{20}H_{34}O_2$ 306	Gupta *et al*., 2018
71.	Different parts	Heneicosanoic acid		$C_{21}H_{42}O_2$ 326	Gupta *et al*., 2018
72.	Different parts	Behenic acid		$C_{22}H_{44}O_2$ 340	Gupta *et al*., 2018
	Aldehydes and ketones and their derivatives				
73.	Pods	trans-2-Nonenal		$C_9H_{16}O$ 140	Selvaraj and Mosses, 2016
74.	Pods	4-Oxononanal		$C_9H_{16}O_2$ 156	Selvaraj and Mosses, 2016
75.	Fruit	4-(B-D-glucopyrano syloxy) benzaldehyde		$C_{13}H_{16}O_7$ 284	Yoshikawa *et al.,* 2007
76.	Fruit	4-Hydroxybenzyl B-D-Glucopyranoside		$C_{13}H_{18}O_7$ 286	Yoshikawa *et al.,* 2007
77.	Peels	10,13-Dimethylpenta-13-decen-1-al		$C_{17}H_{33}O$ 253	Yankov and Ayoub, 1981
78.	Peels	Methyl heptanone		$C_8H_{14}O$ 126	Ayoub and Yankov, 1981
79.	Peels	11,14-Dimethyl hexadecan-14-ol-2-one		$C_{18}H_{36}O_2$ 284	Ayoub and Yankov, 1981
80.	Peels	10, 14-Dimethylhexadecan-14-ol-2-one.		$C_{18}H_{36}O_2$ 284	Ayoub and Yankov, 1981

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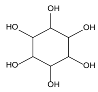
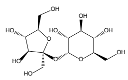
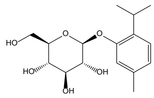
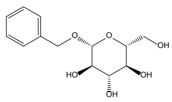
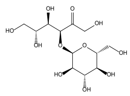
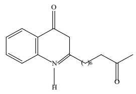
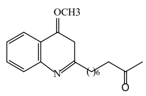
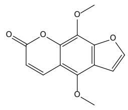
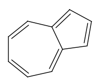
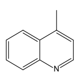
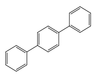
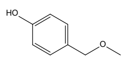
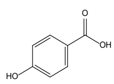
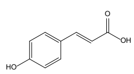
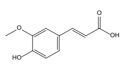
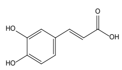
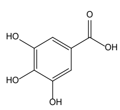
S. No.	Parts	Compound names	Compound structures	Molecular formula and weight	References
	Sugar				
81.	Different parts	Myo-Inositol		$C_6H_{12}O_6$ 180	Gupta *et al*., 2018
82.	Different parts	Sucrose		$C_{12}H_{22}O_{11}$ 342	Gupta *et al*., 2018
83.	Different parts	Thymol-glucopyranoside		$C_{16}H_{24}O_6$ 312	Gupta *et al*., 2018
84.	Fruit	Benzyl B-D-Glucopyranoside		$C_{13}H_{18}O_6$ 270	Yoshikawa *et al.,* 2007
85.	Different parts	Turanose		$C_{12}H_{22}O_{11}$ 342	Gupta *et al*., 2018
	Aromatic compounds				
86.	Aerial Parts	2-(Nonan-8-one)-(1H)-4-quinolone		$C_{18}H_{23}NO_2$ 285	Salama, 2012
87.	Aerial Parts	2-(Nonan-8-one) 4-methoxy-quinoline		$C_{18}H_{26}NO_2$ 288	Salama, 2012
88.	Seeds	Isopimpinellin		$C_{13}H_{10}O_5$ 246	Almalki and Mohammed, 2016
89.	Pods	Azulene		$C_{10}H_8$ 128	Selvaraj and Mosses, 2016
90.	Fruits	4-Methylquinoline		$C_{10}H_9N$ 143	Jeon and Lee, 2014
91.	Fruit	p-Terphenyl		$C_{18}H_{14}$ 230	Rizvi *et al*., 2017
	Phenols and derivatives				
92.	Fruit Unripe	*P*-Hydroxybenzyl methyl ether		$C_8H_{10}O_2$ 138	Watanabe *et al.,* 1961
93.	Leaves	P-Hydroxybenzoic acid		$C_7H_6O_3$ 138	Jing *et al*., 2012
94.	Roots	P-Coumaric acid		$C_9H_8O_3$ 164	Hsouna and Alayed, 2012
95.	Roots	Ferulic acid		$C_{10}H_{10}O_4$ 194	Hsouna and Alayed, 2012
96.	Roots	Caffeic acid		$C_9H_8O_4$ 180	Hsouna and Alayed, 2012
97.	Fruit	Gallic acid		$C_7H_6O_5$ 170	Kumar *et al*., 2008

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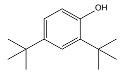
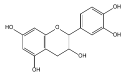
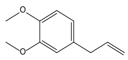
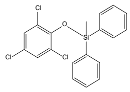
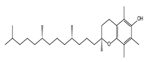
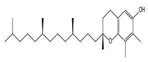
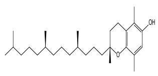
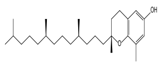
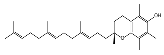
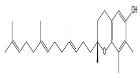
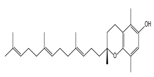
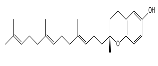
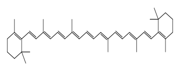
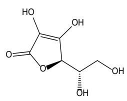
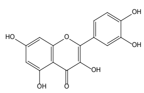
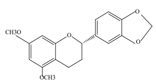
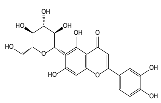
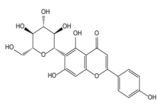
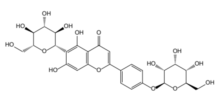
S. No.	Parts	Compound names	Compound structures	Molecular formula and weight	References
98.	Different parts	2,4-Di-tert-butylphenol		$C_{14}H_{22}O$ 206	Gupta *et al.*, 2018
99.	Fruit	Catechin		$C_{15}H_{14}O_6$ 290	Kumar *et al.*, 2008
100.	Peels	Methyl eugenol		$C_{11}H_{14}O_2$ 178	Ayoub and Yankov, 1981
101.	Leaves	2,4,6-Trichlorophenol, diphenylmethyl silyl ether		$C_{19}H_{15}Cl_3OSi$ 392	Selvaraj and Mosses, 2016
	Vitamin and derivatives				
102.	Seeds	α-Tocopherol		$C_{29}H_{50}O_2$ 430	Kalhoro *et al.*, 2002
103.	Seeds	γ-Tocopherol		$C_{28}H_{48}O_2$ 416	Kalhoro *et al.*, 2002
104.	Seeds	β –Tocopherol		$C_{28}H_{48}O_2$ 416	Olatunya *et al.*, 2019
105.	Seeds	Delta-Tocopherol		$C_{27}H_{46}O_2$ 402	Olatunya *et al.*, 2019
106.	Seeds	α –Tocotrienol		$C_{29}H_{44}O_2$ 424	Olatunya *et al.*, 2019
107.	Seeds	γ –Tocotrienol		$C_{28}H_{42}O_2$ 410	Olatunya *et al.*, 2019
108.	Seeds	β –Tocotrienol		$C_{28}H_{42}O_2$ 410	Olatunya *et al.*, 2019
109.	Seeds	Delta-Tocotrienol		$C_{27}H_{40}O_2$ 396	Olatunya *et al.*, 2019
110.	Seeds	β-carotene		$C_{40}H_{56}$ 536	Kalhoro *et al.*, 2002
111.	Leaves	Ascorbic acid		$C_6H_8O_6$ 176	Owoade *et al.*, 2018
	Flavanoids				
112.	Leaf, stem, fruit and roots	Quercetin		$C_{15}H_{10}O_7$ 302	Meena and Patni, 2008
113.	Aerial parts	3, 4 - Methylenedioxy-5, 7-dimethoxy flavanone		$C_{18}H_{18}O_5$ 314	Salama, 2012
114.	Fruit	Isoorientin		$C_{21}H_{20}O_{11}$ 448	Maatooq *et al.*, 1997
115.	Seeds fruits	Isovitexin		$C_{21}H_{20}O_{10}$ 432	Delazar *et al.*, 2006; Gurudeeban *et al.*, 2010a; Maatooq *et al.*, 1997
116.	Fruit seeds	Isosaponarin		$C_{27}H_{30}O_{15}$ 594	Delazar *et al.*, 2006; Gurudeeban *et al.*, 2010a

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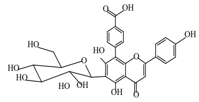
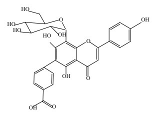
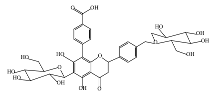
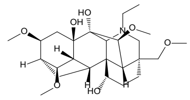
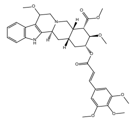
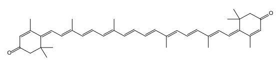
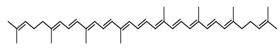
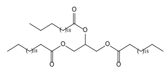
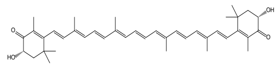
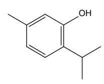
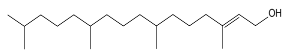
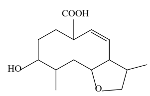
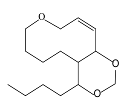
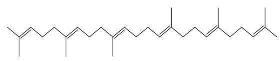
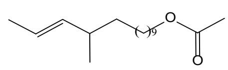
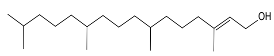
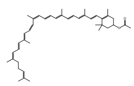
S. No.	Parts	Compound names	Compound structures	Molecular formula and weight	References
117.	Aerial parts	8-C-P-Hydroxy benzoylisovitexin		$C_{28}H_{24}O_{12}$ 552	Maatooq *et al*., 1997
118.	Aerial parts	6-C-P-Hydroxybenzoyl vitexin		$C_{28}H_{24}O_{12}$ 552	Maatooq *et al*., 1997
119.	Aerial parts	8-C-P-Hydroxybenzoylisovitexin 4′-O-glucoside		$C_{35}H_{36}O_{16}$ 712	Maatooq *et al*., 1997
	Alkaloid				
120.	Leaves	Delsoline		$C_{25}H_{41}O_7$ 467	Selvaraj and Mosses, 2016
121.	Pods	Rescinnamine		$C_{35}H_{42}N_2O_9$ 634	Selvaraj and Mosses, 2016
	Pigments				
122.	Leaves	Rhodoxanthin		$C_{40}H_{50}O_2$ 562	Selvaraj and Mosses, 2016
123.	Leaves	Lycopene		$C_{40}H_{56}$ 536	Owoade *et al*., 2018
	Glycerides				
124.	Pods	1,2,3- Propanetriyl docosanoate		$C_{69}H_{134}O_6$ 1059	Selvaraj and Mosses, 2016
	Terpenes				
125.	Leaves	Astaxanthin		$C_{40}H_{52}O_4$ 596	Selvaraj and Mosses, 2016
126.	Pods	Thymol		$C_{10}H_{14}O$ 150	Selvaraj and Mosses, 2016
127.	Leaves	3,7,11,15,-Tetamethyl-2-hexadecen- 1-ol		$C_{20}H_{40}O$ 296	Selvaraj and Mosses, 2016
128.	Aerial parts	Germacr-3-ol-8-en-6, 12-oxy-15-oic acid		$C_{15}H_{24}O_4$ 268	Jeeb *et al*., 2016
129.	Aerial parts	5, 6-[4, butyl-1, 3-dioxino]-7-ene-oxecine		$C_{15}H_{26}O_3$ 254	Jeeb *et al*., 2016
130.	Pods Different parts	Squalene		$C_{30}H_{50}$ 410	Selvaraj and Mosses, 2016; Gupta *et al*., 2018
131.	Leaves	E-11-Methyl-12-tetradecen-1-ol acetate		$C_{17}H_{32}O_2$ 268	Selvaraj and Mosses, 2016
132.	Leaves Different parts	Phytol		$C_{20}H_{40}O$ 296	Selvaraj and Mosses, 2016; Gupta *et al*., 2018
133.	Leaves	Rubixanthin acetate		$C_{42}H_{58}O_2$ 594	Selvaraj and Mosses, 2016

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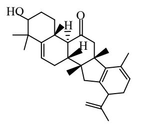
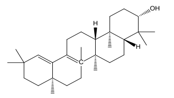
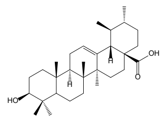
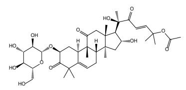
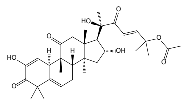
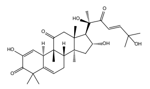
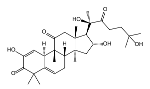
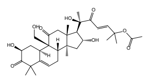
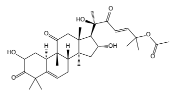
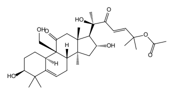
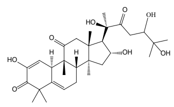
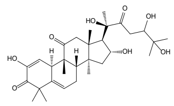
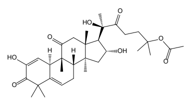
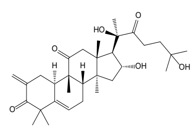
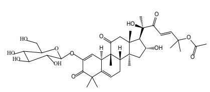
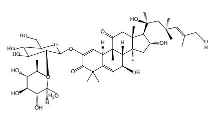
S. No.	Parts	Compound names	Compound structures	Molecular formula and weight	References
134.	Seeds	Citrullonol		$C_{30}H_{42}O_2$ 434	Yankov and Hussein, 1975b
135.	Pods	Germanicol		$C_{30}H_{50}O$ 426	Selvaraj and Mosses, 2016
136.	Fruit	Ursolic Acid		$C_{30}H_{48}O_3$ 456	Srivastava *et al.*, 2013
137.	Leaves	Cucurbitacin B glucoside		$C_{38}H_{56}O_{13}$ 720	Tannin-spitz *et al.*, 2007
138.	Leaves	Elaterin (Cucurbitacin E)		$C_{32}H_{44}O_8$ 556	Wilner and Merenlender, 1964
139.	Leaves	Elatericin B (Cucurbitacin I)		$C_{30}H_{42}O_7$ 514	Wilner and Merenlender, 1964
140.	Leaves	Dihydroelatericin B (Cucurbitacin L)		$C_{30}H_{44}O_7$ 516	Wilner and Merenlender, 1964
141.	Fruit	Cucurbitacins A		$C_{32}H_{46}O_9$ 574	Adam *et al.*, 2001
142.	Seeds	Cucurbitacin B		$C_{32}H_{46}O_8$ 558	Adam *et al.*, 2001
43.	Fruit	Cucurbitacins C		$C_{32}H_{48}O_8$ 560	Adam *et al.*, 2001
144.	Plant material	Cucurbitacins K		$C_{30}H_{44}O_8$ 532	Sturm *et al.*, 2009
145.	Plant material	Cucurbitacines J		$C_{30}H_{44}O_8$ 532	Sturm *et al.*, 2009
146.	Leaves	Dihydro cucurbitacin E		$C_{32}H_{46}O_8$ 558	Jing *et al.*, 2012
147.	Leaves	Dihydro-Epi-Iso-cucurbitacin D		$C_{30}H_{46}O_7$ 518	Jing *et al.*, 2012
148.	Fruit	Colocynthin		$C_{38}H_{54}O_{13}$ 718	Power and Moore, 1910
149.	Fruit	Colocynthosides B		$C_{42}H_{62}O_{15}$ 806	Yoshikawa *et al.*, 2007

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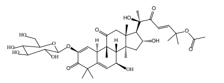
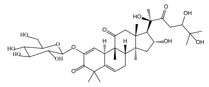
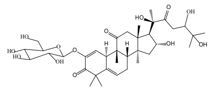
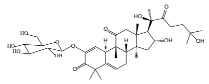
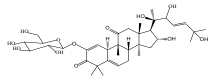
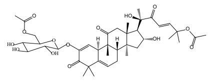
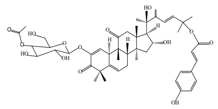
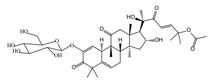
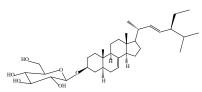
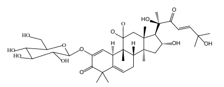
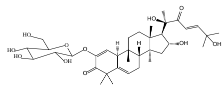
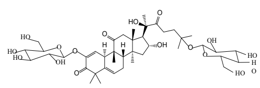
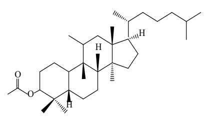
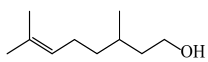
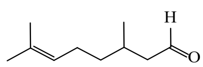
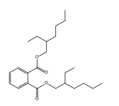
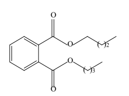
S. No.	Parts	Compound names	Compound structures	Molecular formula and weight	References
150.	Fruit	Colocynthosides A		$C_{38}H_{54}O_{14}$ 734	Yoshikawa *et al.,* 2007
151.	Fruit	Cucurbitacin J 2-O-B-D-glucopyranoside		$C_{36}H_{54}O_{13}$ 694	Yoshikawa *et al.,* 2007
152.	Fruit	Cucurbitacin K 2-O-B-D-glucopyranoside		$C_{36}H_{54}O_{13}$ 694	Yoshikawa *et al.,* 2007
153.	Fruit	Cucurbitacin L 2-O-B-D-glucopyranoside		$C_{36}H_{54}O_{12}$ 678	Yoshikawa *et al.,* 2007
154.	Fruit	Khekadaengoside E		$C_{36}H_{53}O_{12}$ 677	Yoshikawa *et al.,* 2007
155.	Leaves	6′-Acetyl-2-*O*-B-D-glucocucurbitacin E		$C_{40}H_{56}O_{14}$ 760	Chawech *et al.*, 2015
156.	Leaves	25 *P* Coumaroyl-3′-Acetyl-2-*O*-B-D-glucocucurbitacin I		$C_{47}H_{60}O_{15}$ 864	Chawech *et al.*, 2015
157.	Leaves	Cucurbitacin E glucosides.		$C_{38}H_{54}O_{13}$ 718	Tannin-spitz *et al.*, 2007
158.	Leaves	A-Spinasterol-3-O-B-D-glucopyranoside		$C_{35}H_{58}O_{6}$ 574	Jing *et al.*, 2012
159.	Seeds	11-Deoxocucurbitacin-I-2-O-B-D-glucoside		$C_{36}H_{52}O_{13}$ 692	Marzouk *et al.*, 2013
160.	Fruit	2-O-B-D-glucopyranosyl cucurbitacin I		$C_{36}H_{54}O_{11}$ 662	Delazar *et al.*, 2006
161.	Fruit	2,25-Di-*O*-B-D-Glucopyranosyl-Cucurbitacin L		$C_{42}H_{60}O_{17}$ 836	Nayab *et al.*, 2006
162.	Leaves	9,19- Cyclolanostane 3-acetoxy		$C_{32}H_{50}O_{4}$ 498	Selvaraj and Mosses, 2016
163.	Peels	Citronellol		$C_{10}H_{20}O$ 156	Ayoub and Yankov, 1981
164.	Peels	Citronellal		$C_{10}H_{18}O$ 154	Ayoub and Yankov, 1981
	Plasticizer				
165.	Leaves	Bis (2-Ethylhexyl) phthalate		$C_{24}H_{38}O_{4}$ 390	Jing *et al.*, 2012
166.	Pulp powder	Dibutyl phthalate		$C_{16}H_{22}O_{4}$ 27	Kumar *et al.*, 2019

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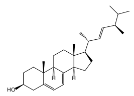
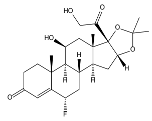
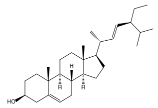
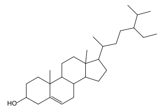
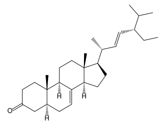
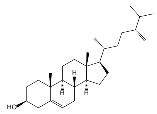
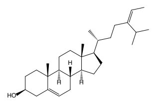
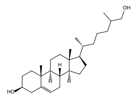
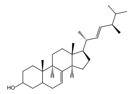
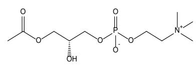
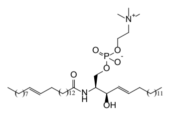
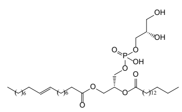
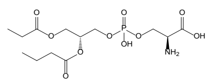
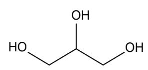
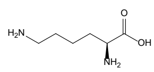
S. No.	Parts	Compound names	Compound structures	Molecular formula and weight	References
	Steroids				
167.	Pods Seeds	Ergosterol		$C_{28}H_{44}O$ 396	Selvaraj and Mosses, 2016; Olatunya *et al.*, 2019
168.	Leaves	Flurandrenolide		$C_{24}H_{33}FO_6$ 436	Selvaraj and Mosses, 2016
169.	Leaves Seeds	Stigmasterol		$C_{29}H_{48}O$ 412	Selvaraj and Mosses, 2016; Olatunya *et al.*, 2019
170.	Leaves Seeds	B-Sitosterol		$C_{29}H_{50}O$ 414	Meena *et al.*, 2011; Olatunya *et al.*, 2019
171.	Leaves	A-Spinasterone		$C_{29}H_{46}O$ 410.	Jing *et al.*, 2012
172.	Seeds	Campesetrol		$C_{28}H_{48}O$ 400	Olatunya *et al.*, 2019
173.	Seeds	5-Avenasterol		$C_{29}H_{48}O$ 412	Olatunya *et al.*, 2019
174.	Different parts	Hydroxy Cholesterol		$C_{27}H_{46}O_2$ 402	Gupta *et al.*, 2018
175.	Different parts	Ergosta-7,22-dien-3-B-ol		$C_{28}H_{46}O$ 398	Gupta *et al.*, 2018
	Phospholipids				
176.	Seeds	Lysophosphatidyl choline		$C_{10}H_{22}NO_7P$ 299	Olatunya *et al.*, 2019
177.	Seeds	Sphingomyelin		$C_{47}H_{93}N_2O_6P$ 813	Olatunya *et al.*, 2019
178.	Seeds	Phosphatidyl glycerol		$C_{40}H_{77}O_{10}P$ 749	Olatunya *et al.*, 2019
179.	Seeds	Phosphatidyl serine		$C_{13}H_{24}NO_{10}P$ 385	Olatunya *et al.*, 2019
180.	Different parts	Glycerol		$C_3H_8O_3$ 92	Gupta *et al.*, 2018
	Amino acids				
181.	Seeds Pulp Rind	Lysine		$C_6H_{14}O_2N_2$ 146	Abudayeh *et al.*, 2016

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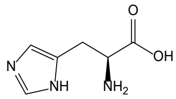
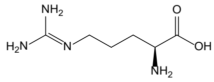
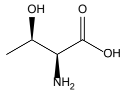
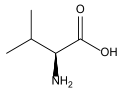
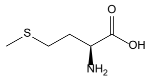
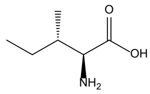
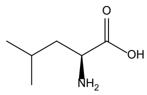
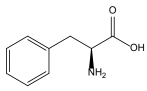
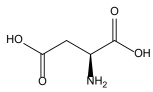
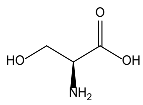
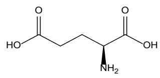
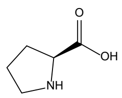
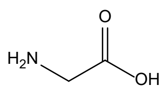
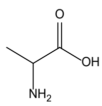
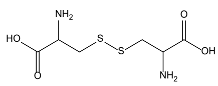
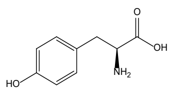
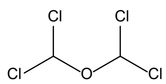
S. No.	Parts	Compound names	Compound structures	Molecular formula and weight	References
182.	Seeds Pulp Rind	Histidine		$C_6H_9O_2N_3$ 155	Abudayeh *et al*., 2016
183.	Seeds Pulp Rind	Arginine		$C_6H_{14}O_2N_4$ 174	Abudayeh *et al*., 2016
184.	Seeds Pulp Rind	Threonine		$C_4H_9O_3N$ 119	Abudayeh *et al*., 2016
185.	Seeds Pulp Rind	Valine		$C_5H_{11}O_2N$ 117	Abudayeh *et al*., 2016
186.	Seeds Pulp Rind	Methionine		$C_5H_{11}O_2NS$ 149	Abudayeh *et al*., 2016
187.	Seeds Pulp Rind	Isoleucine		$C_6H_{13}O_2N$ 131	Abudayeh *et al*., 2016
188.	Seeds Pulp Rind	Leucine		$C_6H_{13}O_2N$ 131	Abudayeh *et al*., 2016
189.	Seeds Pulp Rind	Phenylalanine		$C_9H_{11}O_2N$ 165	Abudayeh *et al*., 2016
190.	Seeds Pulp Rind	Aspartic acid		$C_4H_7O_4N$ 133	Abudayeh *et al*., 2016
191.	Seeds Pulp Rind	Serine		$C_3H_7O_3N$ 105	Abudayeh *et al*., 2016
192.	Seeds Pulp Rind	Glutamic acid		$C_5H_9O_4N$ 147	Abudayeh *et al*., 2016
193.	Seeds Pulp Rind	Proline		$C_5H_9O_2N$ 115	Abudayeh *et al*., 2016
194.	Seeds Pulp Rind	Glycine		$C_2H_5O_2N$ 75	Abudayeh *et al*., 2016
195.	Seeds Pulp Rind	Alanine		$C_3H_7O_2N$ 89	Abudayeh *et al*., 2016
196.	Seeds Pulp Rind	Cystine		$C_6H_{12}O_4N_2S$ 240	Abudayeh *et al*., 2016
197.	Seeds Pulp Rind	Tyrosine		$C_9H_{11}O_3N$ 181	Abudayeh *et al*., 2016
	Ether				
198.	Pulp powder	Bis(dichloro methyl) ether		C_2H_2ClO 182	Kumar *et al*., 2019

Table 2: *Pharmacological activities of different extracts obtained from different parts of C. colocynthis.*

S. No.	Activity	Part of plant	Extracts	References
1.	Anti-Cancer Or Anti-Tumor	Seeds Plant Pulp powder	Different extracts Aqueous	Tannin-Spitz *et al*., 2007; Belkin and Fitzgerald, 1952; Kafshgari *et al*., 2019
2.	Jaundice	Roots	-	Pravin *et al*., 2013
3.	Urinary Diseases	Roots	-	Pravin *et al*., 2013
4.	Rheumatism	Roots Roots	-	Pravin *et al*., 2013; Batanouny, 1999
5.	Snake Bite	Whole Plant	Methanol	Asad *et al*., 2012
6.	Anti-asthmatic	Roots Fruit	Powder oral Ethanolic	Savithramma *et al*., 2007; Genwa *et al*., 2017
7.	Anti-Inflammatory	Leaves Immature fruit and seeds	Methanol Aqueous Organic solvents	Marzouk *et al*., 2010; Rajamanickam *et al*., 2010; Marzouk *et al*., 2011
8.	Analgesic	Immature fruit and seeds	Organic solvents	Marzouk *et al*., 2011
9.	Amenorrhea	Roots	-	Batanouny, 1999
10.	Helmintholytic	Leaves	Different	Talole *et al*., 2013
11.	Osteoarthritis	Roots	Ethanol	Akhzari *et al*., 2015
12.	Joint Pains	Root	-	Batanouny, 1999
13.	Ophthalmia	Roots	-	Batanouny, 1999
14.	Uterine Pain	Roots	-	Batanouny, 1999
15.	Purgative	Fruit/Pulp	-	Batanouny, 1999
16.	Antipyretic	Fruit	-	Batanouny, 1999
17.	Anti-Malarial	Fruit Fruit pulp	Methanol Ethanolic	Tariq *et al*., 2016; Feiz *et al*., 2017
18.	Anti-leishmanial	Plant Fruit	Aqueous Crude methanol	Rani and Dantu, 2015; Tariq *et al*., 2016
19.	Anti-Ulcers	Seeds Fruits	Aqueous and ethanolic	Gill *et al*., 2011; Reddy *et al*., 2012
20.	Hair Loss Treatment	Fruits Fruit	Ethanol and pet. ether Pet.ether	Roy *et al*., 2007; Dhanotia *et al*., 2011
21.	Bronchitis	Fruit	-	Gurudeeban *et al*., 2010a
22.	Nephro protective	Fruit	Ethanolic	Adeyemi *et al*., 2017
23.	Anti-Gonorrhea.	Fruit/Pulp	-	Uma and Sekar, 2014
24.	Anti-Diabetic	Fruit Seeds	- Oil	Rahbar and Nabipour, 2010; Heydari *et al*., 2019
25.	Toothache	Roots	-	Qureshi and Bhatti, 2008
26.	Mastitis	Fruit pulp	Ethanol	Singh, 2019
27.	Constipation	Seeds	-	Bahmani *et al*., 2014
28.	Anti-diarrheal	Fruits	Hydroalcoholic	Dhakad, 2017
29.	Acute stomach ache	Fruits	Oral	Meena *et al*., 2014
30.	Bowel complaints	Seed oil	-	Meena *et al*., 2014
31.	Epilepsy	Seed oil	-	Meena *et al*., 2014
32.	Dropsy	Fruits	Juice	Meena *et al*., 2014
33.	Boils and pimples	Fruits and roots	Mixture with water	Meena *et al*., 2014
34.	Hepatitis	Fruit	Decoctation	Meena *et al*., 2014
35.	Abortion	Pulp (dried and powdered)	Oral	Meena *et al*., 2014
36.	Anti-Microbial	Leaf Pulp Fruit Plant Whole Plant	Methanol Methanol Chloroform Methnolic Acetone	Gurudeeban *et al*., 2010b; Shaikh *et al*., 2016; Kim *et al*., 2014; Al-Askar *et al*., 2014; Mahendiran and Umavathi, 2015

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S. No.	Activity	Part of plant	Extracts	References
37.	Antineoplastic Action	Fruit	-	Faust *et al*., 1958.
38.	Anti-Implantation	Plant	Ethanolic and benzene	Prakash *et al*., 1985.
39.	Anti-Oxidant	Pulp Seeds Seeds Immature fruit and seeds Fruit Leaves	Hydro-ethanol Hydro-methanol, ethyl acetate Methanol/water Organic extracts Benzene, chloroform, methanol Different extracts	Dallak, 2011; Benariba *et al*., 2013; Yasir *et al*., 2016; Marzouk *et al*., 2016; Vakiloddin *et al*., 2015; Nessa and Khan, 2014
40.	Antimyco bacterial activity	Aerial parts and ripe deseeded fruits	Methanol	Mehta *et al*., 2013
41.	Xanthine oxidase inhibition	Leaves	Different extracts	Nessa and Khan, 2014
42.	Radical scavenging potential	Fruit	Methanolic	Kumar *et al*., 2008
43.	Anti-fertility effect	Fruit Roots	Ethanol Ethanol	Chaturvedi *et al*., 2003; Mali *et al*., 2001
44.	Anti-convulsant	Fruit	Hydroalcoholic extract	Mehrzadi *et al*., 2016
45.	Lipoxygenase activity	Seed	-	Al-Khalifa, 1996
46.	Antifungal	Fruit, seeds Floral parts Seeds Plant	Aqueous Ethanolic Petroleum ether Various extract	Marzouk *et al*., 2010b; Hadizadeh *et al*., 2009; Sari *et al*., 2014; Bokhari *et al*., 2013
47.	Hepato protective	Fruit Fruit	Benzene, chloroform, methanolic Ethanolic	Vakiloddin *et al*., 2015; Adeyemi *et al*., 2017
48.	Antibacterial	Leaves Roots, stems, leaves and three maturation stages of its fruit and seeds Immature fruits and seeds) Leaves and fruits Pulp Plant	Methanolic Aqueous and diluted acetone Aqueous (water and ethanolic) Aqueous and dealcoholized Different extracts	Gurudeeban *et al*., 2010; Marzouk *et al*., 2009; Marzouk *et al*., 2010b; Najafi *et al*., 2010. Patel and Trivedi, 1957 Mehni *et al*., 2014
49.	Anticandidal	Roots, stems, leaves and three maturation stages of its fruit and seeds	Aqueous and diluted acetone	Marzouk *et al*., 2009
50.	Hypoglycemic	Rind Seedless pulp	Aqueous	Abdel-Hassan *et al*., 2000; Mohammad *et al*., 2009
51.	Normo-hypoglycemic	Dried seedless pulp	Ethanol	Mohammad *et al*., 2009b
52.	Insulinotropic actions	Dried seedless pulp	Ethanol	Mohammad *et al*., 2009a
53.	Anti-Hyper Lipidemic	Seed powder Dried seedless pulp Pulp	Capsule Ethanol Hydro-ethanol	Rahbar and Nabipour, 2010; Mohammad *et al*., 2009b; Dallak, 2011
54.	Antihyper glycemic	Seeds	Aqueous	Lahfa *et al*., 2017
55.	Immuno stimulating activity	Plant	Hot water polysaccharide	Bendjeddou *et al*., 2003
56.	Anti-obesity	Flesh powder	70% Ethanol	Jemai *et al*., 2018
57.	Anti-angiogenesis	Fruit	Ethyl acetate	Gaikwad *et al*., 2019
58.	Anti-arthritic	Fruit	Hydroalcoholic	Kachhawah *et al*., 2016
59.	Anti-biofilm	Seeds	Ethyl acetate	Almalki and Mohammed, 2016
60.	Anti-depressant	Fruit	Ethanol	Nafisi *et al*., 2016
61.	Spasmogenic activity	Whole plant	Aquoeus and n-butanol	Faisal *et al*., 2018
62.	Oral mucosal disease	Pulp powder	Aqueous	Kafshgari *et al*., 2019
63.	Polycystic ovarian syndrome	Pulp powder	Hydro-ethanolic	Barzegar *et al*., 2017
64.	Antimetallo proteinases	Peels	Aqueous	Zioud *et al*., 2019
65.	Wound healing	Different parts	Methanolic	Gupta *et al*., 2018
66.	Benign prostatic hyperplasia	Fruit	Cucurbitacin E glucoside	Basha *et al*., 2019
67.	Parkinson's disease	-	-	Chen *et al*., 2019
68.	Anti-platelets activity	Plant	Hydro-alcoholic	Alhawiti, 2018
69.	Profibrinolytic activity	Plant	Hydro-alcoholic	Alhawiti, 2018

Table 3: *Pesticidal activities of different extracts obtained from different parts of C. colocynthis.*

S. No.	Pests	Part of plant	Extracts/ form	References
1.	Culex quinquefasciatus	Leaf Whole plant	Oleic and linoleic acid	Mullai and Jebanesan, 2007; Rahuman *et al*., 2008
2.	Aedes aegypti Culex quinquefasciatus	Leaf	-	Rahuman and Venkatesan, 2008
3	Anopheles stephensi Liston	Whole plant	Hexane, diethyl ether, dichloromethane, ethyl acetate	Arivoli *et al*., 2012
4.	Culex pipiens Culiseta longiareolata	Fruit	Aqueous	Merabti-Brahim *et al*., 2016
5.	Bactrocera zonata	Fruit	-	Rehman *et al*., 2009
6.	Aphids, *Lipaphis erysimi*	Aerial parts	Ethanolic	Soam *et al*., 2013
7.	Tribolium castaneum	Fruit powder	Ethanolic	Nadeem *et al*., 2012
8.	Spodoptera littoralis	Fruit	Methylene chloride and hexane.	Rawi *et al*., 2011
9.	Locust, *Chrotogonus trachypterus*	Fruit	Methanol	Mollashahi *et al*., 2017
10.	Cowpea beetle, *Callosobruchus maculatus*	Seeds	Successive extraction	Dimetry *et al*., 2015
11.	Dermestes maculatus	Seeds	Hexane / oil	Akpotu *et al*., 2015
12.	Teteanychus urticae Sitophilus oryzea Sitophilus zeamais	Fruit	4- methylquinoline	Jeon and Lee, 2014
13.	*Callosobruchus maculatus*; cowpea	Seeds	Chloroform	Dimetry *et al*., 2007
14.	Aphis craccivora	Fruit	Ethanol	Torkey *et al*., 2009
15.	Aphid, *Rhopalosiphum padi*	Root, stem, leaf and fruit	Aqueous	Khalid, 2015
16.	Amphistome parasite, *Orthocoelium scoliocoelium*	Fruit pulp	Alcohol	Swarnakar and Kumwat, 2014
17.	M. incognita	Fruit	Acetone Water	Muniasamy *et al*., 2010; Gad *et al*., 2018
18.	*Meloidogyne* spp.	Pulp, seeds, whole fruit	Methanol	Rizvi and Shahina, 2014
19.	Haemonchus contortus	Fruit	Crude aqueous methanol extract	Ahmed *et al*., 2019
20.	*Rhipicephalus* (*Boophilus*) *Microplus*	Roots	Petroleum ether, hexane, methanol	Loach *et al*., 2019
21.	Spodoptera litura	Fruit	Cucurbitacin E	Ponsankar *et al*., 2019
22.	*Musca domestica* (House fly)	Different parts	Aqueous and ethanolic	Farah, 2017

Steroids like β-sitosterol and stigmasterol were also investigated for their nematotoxic effect and were found active against an economically important cyst nematode, *Heterodera zeae* (Bano *et al*., 2019). Flavonoids, quercetin and isovitexin showed promising activity against *Haemonchus contortus* and *M. incognita* respectively (Castillo-Mitre *et al*., 2017; Atolani *et al*., 2014). According to a research, a diterpene, phytol is involved in inhibition of root-knot nematodes, induced by the production of tocopherol (Fujimoto *et al*., 2021). Effect of amino acids is also studied against phytonematodes and as mentioned in Table 1, *C. colocynthis* also possess variety of amino acids among them the nematicidal evaluation of L-arginine, L-glutamic acid, ascorbic acid, alanine, glycine, histidine, threonine, phenyalinine, valine, l-lysine, leucine, aspartic acid and methionine had been reported and resulted in efficient nematicidal responses (Siddiqui and Shaukat, 2002).

The nematotoxic activity of terpenoids, thymol and citronellol is reported against *Caenorhabditis elegans and Ascaris suum* (Lei *et al*., 2010; Abdel-Rahman *et al*., 2013), whereas ursolic acid, was found to be nematicidal against root-knot nematode, *Meloidogyne incognita* (Begum *et al*., 2008). *C.colocynthis* is an easy source of cucurbitacins which are biologically active component for various pharmacological activities (Chung *et al*., 2015). As far as the nematicidal investigation of cucurbitacins is concerned, Nemarioc-

AL and Nemafric-B are phytonematicides, containing cucurbitacin A and B respectively as active ingredients that are being investigated and developed in South Africa as a substitute for the control of *Meloidogyne* species (Dube and Mashela, 2017). A research study was also conducted to compare the nematicidal effect of these phytonematicides and their purified active ingredients and concluded that the cucurbitacin-containing phytonematicides were more active against phytonematodes than their purified active ingredients (Dube *et al*., 2019). In another study, ripe, unripe and powdered form of fruits was investigated for nematicidal activity and was found to be active against larvae of *M. incognita* (Khatri *et al*., 2020). From the literature cited above, it is evident that the phytochemicals present in *C. colocynthis* fruits are lethal for the nematodes and this research data will provide an overview of the type of compounds responsible for mortality of nematodes and will enlighten the new horizons for nematode management other than harmful and most conventional chemical nematicides.

Fatty acids, phenols, esters, alcohols, steroids and terpenoids including cucurbitacins are some of the secondary metabolites isolated from *C. colocynthis*, nematicidal property of which have been already reported and have proved that application of extracts of different parts of *C. colocynthis* could serve as a promising candidates for biocontrol of phytonematodes. Practically, the use of this plant is easier as it is a wild plant that grows easily in desert and does not require much water for nourishment, so it could be easily available resource to the poor farmers not as the chemical pesticides, expensive and hazardous to health. Phytonematicides are easily accessible and bio-degradable, are therefore environmentally friendly compared to the synthetic pesticides. It can be said that the use of botanical means may serve as a substitute to the chemicals in order to bring sustainability to agriculture. The dynamic usage of *C. colocynthis* in medicinal, pesticidal and nematicidal horizons along with its numerous secondary metabolites have established the importance of this plant for future proespects and nominate it as a potential formulation of bio-rational nematicidal solution to include in Integrated Nematode Management (INM) programs. A patent filed in 2019 by Prof. Dr. Shahina Fayyaz, Erum Iqbal, Shaheen Faizi and Sonum Khatri of NNRC product (NNRC-82) composed of *C. colocynthis* is effective against agricultural pests including nematodes.

Recommended dose of NNRC product (NNRC-82)
Regular application is recommended each after six months for all types of field plants.

- For crop plantation: Apply NNRC-82 @ 2 kg a.i./ ha at sowing.
- For tree plantation: Apply NNRC-82 @ 13 g/ m^2 (about 9 m^2 around the tree trunk) just before flowering.

Novelty Statement

The given information in this review article highlights the importance of *Citrullus colocynthis* L. Schrad as a promising biological and pesticidal agent useful for the treatment of various medicinal ailments as well as reducing different pests that are harmful for the crop yield and emphasize the need to utilize the useful effect of this plant against nematodes.

Author's Contribution

Sonam Khatri searched the related articles and wrote the manuscript,Prof. Shaheen Faizi supervised in writing manuscript, Prof. Shahina Fayyaz critically reviewed and help in writing manuscript, Dr. Erum Iqbal helped in compiling the data

Conflict of interest
The authors have declared no conflict of interest.

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