Phytochemistry and pharmacological activities of *Saponaria officinalis* L.: A review

Satish CHANDRA¹*, Dharmendra S. RAWAT², Arun BHATT³

¹Government Degree College Tiuni, Department of Botany, Dehradun (248199) Uttarakhand, India; satishchandrasemwal07@gmail.com (*corresponding author)
²Govind Ballabh Pant University of Agriculture and Technology, Department of Biological Sciences, CBSSH Pantnagar, Uttarakhand, India; drds_rawat@yahoo.com
³GBPIET Ghurdauri, Department of Biotechnology, Pauri Garhwal (Uttarakhand) 246194, India; arun.bhatt@rediffmail.com

Abstract

*Saponaria officinalis* is an important medicinal plant cultivated in different parts of the globe for its beautiful flowers. Species is commonly known as soapwort. Central Europe is considered as native place for the species and has been introduced in Northern Asia, West Asia, Northern Europe and America. Plant of the species are perennial, stem erect, branched, leaves ovate or ovate-lanceolate, inflorescence dense cymes, calyx green or reddish, often cleft, petals pink to white, fruit capsules, seeds tuberculate-reniform and numerous per fruit. Indigenous people of different parts of the world use this species to cure various ailments. Traditionally roots of the species have been used as urine remover. It is also used for cough, bronchitis, stomach disorders, bone deformations, rheumatism, pimples, skin diseases, bile disorders, liver problems and respiratory system diseases. The leaves were rubbed on the skin as a repellent and also used as sanitizer, diuretic and in liver diseases. Saporins are ribosome inhibitory proteins and play important role for anticancer properties. Different types of saponins are synthesized by the species exhibit anticancer, antimicrobial, insecticidal and antioxidant properties. The present review is focused on the traditional medicinal uses of species along with phytochemical and pharmacological studies. This review will provide a ground for future research of the species.

**Keywords:** anticancer; saponaria; saponin; saporin; triterpenoid saponins

Introduction

*Saponaria* L. is an ornamental plant belonging to the family Caryophyllaceae of angiosperms. This genus is represented by 42 accepted species worldwide (POWO, 2019a). The generic name *Saponaria* was coined by Linnaeus from Greek word ‘sapon’ mean ‘soap’ because roots of some species of the genus were being used as a substitute for soap. This genus belongs to subfamily Caryophylloideae, tribe Caryophylleae of the family Caryophyllaceae (Greenberg and Donoghue, 2011). *Saponaria officinalis* L. is one of the common species of the genus. The specific epithet ‘officinalis’ was used in medicine originally for a workshop or shop then herbstore, pharmacy or drug-store (Stearn, 1983). *Boottia saponaria* Neck., *Boottia vulgaris* Neck., *Lychnis officinalis* Scop., *Lychnis saponaria* Jess., *Saponaria officinarum* Rupr. and *Saponaria vulgaris* Pall. are synonyms of the *Saponaria officinalis* (POWO, 2019a). This plant species is commonly known as
soapwort and cultivated in various parts of the world for its various medicinal properties and beautiful white or pink flowers.

Plants are perennial, stem erect, branched, 30-90 cm; leaves are ovate or ovate-lanceolate, blade strongly 3(-5)-veined. Inflorescence dense cymes. Calyx 15-25 mm, green or reddish, often cleft; petals are pink to white; stamen 10; style 2. Fruit capsules; seeds tuberculate-reniform, numerous per fruit. Species grows on waste places, along stream sides and road sides.

Individual flowers are protandrous and open in the evening and remain open for approximately 72 hours. Development of complete flowers passes through four stages. In the early male phase first whorls of stamens extends from the corolla tube and dehisces. The late male phase is marked by emergence of the second whorl of stamens. The early female phase corresponds to the initial protrusion of the stigmas from the corolla tube. In the late female phase stigmas are curling back towards the petals, anthers are no longer present on the stamens. Study of floral biology on *Saponaria officinalis* indicates that there is a close association between colour change and gender transition in flowers of the species. Moreover, transition from male to female stage in a flower is directly correlated with transition in petal colour, from white to pink. Transition in petal colour in directly related to anthocyanin concentration in the petals. Flowers in female phase are found to have significantly higher anthocyanin concentration than in the male phase. The colour change in flower also corresponded with decrease in male sexual function (pollen grain viability). Colour change in the different parts of the plant is phenotypically plastic. Usually, plants grown in full sun had a more extensive colour change than those grown in shaded areas. But, this property of the plant changes when environmental factors change. Petals are usually wider and longer in female phase flowers compared to male phase flowers (Jabbari *et al*., 2012; Davis *et al*., 2014).

Several reviews have been published which deal with medicinal plants of family Caryophyllaceae and their biomedical properties (Arora and Sharma, 2012; Mamadalieva *et al*., 2014; Chandra and Rawat, 2015; Chandra *et al*., 2016). But detailed account of medicinal and phytochemical properties is still lacking for this species. The present work is focused on medicinal and phytochemical properties of the species to fill the knowledge gap.

**Nativity**

Highest diversity of the genus *Saponaria* L. is centred in the temperate Eurasia, chiefly in the Mediterranean and Irano-Turanian region. These areas are considered as centre of origin for this genus (Bittrich, 1993). Central Europe is considered native place for the species *Saponaria officinalis* (Shan-Huah *et al*., 2010). The species has been introduced in Northern Asia, West Asia, Northern Europe and America (POWO, 2019 b).

**Medicinal properties**

Leaves, root and whole plant of the species are used to treat various ailments shown in Table 1.
Table 1. Traditional medicinal uses of the *Saponaria officinalis*

| Part used | Used in disease                                                                 | Country | References                      |
|-----------|----------------------------------------------------------------------------------|---------|---------------------------------|
| Root      | It is used as urine remover. It is also a drug for cough, bronchitis, stomach disorders, bone deformations, rheumatism, pimples, skin diseases, bile disorders, liver problems and respiratory system diseases | Turkey  | Korkmaz and Ozcelik, 2011       |
|           |                                                                                  | Acne    | Said et al., 2002               |
| Stem and root | To treat rheumatic pains, as depurative, diuretic and emetic, decoction is taken orally | Morocco | Merzouki et al., 2000           |
|            | Rheumatism, respiratory regulation, diuretic                                    | Turkey  | Karaman and Kocabas, 2001       |
| Root and leaf | Diaphoretic and tonic. Used for rheumatic diseases, syphilis, tetter, for jaundice and engorgement of the abdominal viscera | Brazil  | Medeiros and Albuquerque, 2012  |
| Leaves    | Diuretic, bronchitis, expectorant, sudorific                                   | Turkey  | Ugulu et al., 2009              |
|           | Sanitizer, liver diseases and diuretic                                           | Italy (Sardinia) | Loi et al., 2004              |
|           | The leaves were rubbed on the skin as a repellent                              | (Rome) Italy | Guarrera, 1999                  |
| Whole plant | Antalgic Iberian Peninsula                                                    | Greece  | Hanlidou et al., 2004           |
|           | Constipation, gall disorders, gallstones, haemostatic, common cold, arthritis, rheumatisms, eczema, hair loss, herpes, kidney stones, antipyretic, stimulant. | Italy (Sardinia) | Ballero et al., 2001           |
|           | Skin disease                                                                   | Italy (Sardinia) | Ballero et al., 2001           |
|           | Chopped and applied topically in treatment of all skin diseases                 | (Campania) Italy | Novella et al., 2013           |

**Ribosome inactivating proteins**

Ribosome-inactivating proteins (RIPs) are the plant proteins that enzymatically damage ribosomes in a catalytic manner, thus inhibiting protein synthesis. RIPs inhibit protein synthesis by depurinating an adenine residue present in a conserved stem-loop region of 23/26/28S ribosomal RNA (rRNA) and ultimately removal of adenine, thereby causing an irreversible arrest in protein synthesis (Lombardi et al., 2010). RIPs can eliminate adenines from any kind of nucleic acid namely rRNA, tRNA, mRNA, viral RNA and even DNA. Such activity of RIPs is lead to rename with the more significant and systematic denomination of adenine polynucleotide glycosylases (Girbes et al., 2004). RIPs are present in a large number of plants species and also have been detected from fungi, algae and bacteria. First identified RIPs were ricin and abrin from the seeds of *Ricinus communis* and *Abrus precatorius* respectively (Stirpe, 2004). The angiosperm families *i.e.* Caryophyllaceae, Sambucaceae, Cucurbitaceae, Euphorbiaceae, Phytolacaceae and Poaceae show high RIPs activity (Girbes et al., 2004).
RIPs are present in multiple forms and have been classified as type 1 RIP consists of single chain, strongly basic proteins, having enzymatic activity. They inhibit cell-free protein synthesis but are relatively non-toxic to cells and animals. Saporin from *Saponaria officinalis*, trichoanguin from *Trichosanthes cucumerina*, momordin I and momordin II from *Momordica charantia* are examples of this category. Type 2 RIPs consist in enzymatic chain A similar to type 1 RIPs which is linked to a slightly larger chain B. Chain B is a lectin specific for sugars generally with the terminal free D galactose structure. In type 2 RIPs chain B binds to cell membranes facilitating the entry of chain A into the cell. Inside the cell, chain A damage ribosomes which cause subsequent cell death. This group includes ricin, abrin and other potent toxins. Type 1 RIPs are less toxic as compare to type 2 RIPs because they lack B-chain and do not enter inside the cell. However, they can be toxic if they are conjugated to molecules capable to deliver RIPs type 1 into the cell. Third type of RIPs, type 3 RIPs also has been proposed which synthesized as a proenzyme and activated after the removal of a short internal peptide segment. Maize b-32 RIP is example of type 3 RIPs and activated after the removal of a short internal peptide segment (Girbes *et al.*, 2004; Stirpe, 2013).

Saporins are type 1 RIPs extracted from different tissues of the soapwort plant. The saporin was detected and examined in leaves, stems, roots, flowers, and fruits except immature seeds (Ferreras *et al.*, 1993). High levels of activity were found in roots and mature seeds and leaves despite of being old or young leaves. Saporin expression also has been studied in callus, cell suspensions, and root cultures from soapwort explants. The highest activity was found in callus extracts and lower levels were reported in the root extracts (Di Cola *et al.*, 1997). An isoform 6 of saporin (SO6) has been isolated from the seeds of *Saponaria officinalis*. Savino *et al.* (2000) studied crystal structure of SO6 and its interaction with ribosomes. They concluded that SO6 is made up of two domains, the N-terminal domain which is predominated by six β-sheets and the C-terminal domain which is predominated by eight α-helices (Figure 1). The contact surface of SO6 with ribosome is present inside the C-terminal region.

![Figure 1](https://doi.org/10.2210/pdb1QI7/pdb)

Saporin-L1 (SAP) is another RIP type 1 saporin isolated from *Saponaria officinalis* (soapwort) leaves. It is homologue of ricin A-chain (RTA). RTA is the catalytic subunit of RIP ricin. SAP exhibits N-glycohydrolase activities on 80S ribosomes, poly (A) RNA, and other cellular DNA and RNAs. It releases multiple adenines from ribosomes (Ho *et al.*, 2009). SAP is a monomer with two domains: N-terminal with β-sheet with a short intervening α-helix and a C-terminal contains α helical cluster that is followed by antiparallel β-sheet (Figure 2).
Saponins

The term saponin derived from the Latin (Greek?) word *sapo*, which means ‘soap’. These characterized by forming foams when shaken with water and chemically referred as tri-terpene and steroid glycosides. Saponins consist of nonpolar aglycones coupled with one or more monosaccharide moieties. This combination of polar and non-polar structural elements in saponins explains their soap-like properties in aqueous solutions (Vincken *et al.*, 2007). Saponins are made up of two components: aglycone and a sugar moiety. The two components are linked at C-3 between aglycone and a sugar chain via glycosidic linkage (El Aziz *et al.*, 2019). Saponins are classified on the basis of their aglycone or sapogenin skeleton into two groups. The first group characterized by presence of steroidal saponins and second group characterized by presence of the triterpenoid saponins. The steroidal saponins are mainly found in monocotyledons while, triterpenoid saponins occur mainly in the dicotyledons (Sparg *et al.*, 2004; Man *et al.*, 2010). Triterpene saponins are found in the Caryophyllaceae family (Bottger and Melzig, 2011). Basic structure of the triterpene is 30 carbons, which is made derived from three monoterpenes (10 carbon atoms) (Rahimi *et al.*, 2019). On the basis of the number of sugar moieties linked to the aglycone nucleus, triterpenoid saponins are further classified into two groups: monodesmosidic and didesmosidic. In the monodesmosidic triterpenoid a single sugar chain is attached at C-3. In the bidesmosidic triterpenoid two sugar chains are attached: one at C-3 (ether linkage) and other at C-28 (ester linkage) or at C-24 (ether linkage) (El Aziz *et al.*, 2019). In *S. officinalis* four aglycones hederagenin, hydroxyhederagenin, gypsogenin and quillaic acid are found and form the triterpenoid glycosides; they are mostly bidesmosides (Smulek *et al.*, 2017) Figures 3 and 4.
**Figure 3.** Aglycones structure (a: gypsogenin, b: hederagenin, c: quillaic acid, d: hydroxyhederagenin)  
(Source: www.chemspider.com)

Jia *et al.* (1998) isolated saponariosides A-B, Jia *et al.* (1999) isolated saponarioside C-H and Koike *et al.* (1999) isolated saponarioside I-M from the whole plant of *S. officinalis*. Moniuszko-Szajwaj *et al.* (2013) isolated vaccaroside D and dianchinenoside B, saponarioside C, D, F, G, I, K, L, hydroxygypsogenic acid derivative compound 1-2 and gypsogenic acid derivative compound 3 from the roots. Lu *et al.* (2015) isolated quillaic acid derivative compound 1-9 and gypsogenin derivative compound 10-14 from the roots.
Figure 4. Structure of saponins of *Saponaria officinalis*
Source: Jia et al. (1998, 1999), Koike et al. (1999), Moniuszko-Szajwaj et al. (2013), Lu et al. (2015)
Floral scent composition of *Saponaria officinalis*

Floral scent composition of *Saponaria officinalis* was studied by Jurgens et al. (2003). The floral scent of this species is dominated by methylbenzoate which is accounted for 68.7% of the total scent. Apart from this fatty acid, its derivatives n-hexanal, n-heptanal, n-octanal, n-nonanal, n-decanal. Benzenoids derivatives, methylbenzene and 1,2-dimethylbenzene are also present (Jurgens et al., 2003).

**Essential oil composition**

Phytochemical analysis of essential oil obtained from the fresh flowers and shoots was done by Petrović et al. (2017). They isolated 87 compounds including phytol, tricosane-6,8-dione, patchouli alcohol from the shoot and 66 compounds including patchouli alcohol, heneicosane and tricosane from the flowers. They further elucidated that non-terpenoid compounds contribute higher in the essential oil of shoots, while oxygenated sesquiterpenoid and non-terpenoid compounds are present equally in the flower oil.

**Saporin as anticancer agents**

Several studies have revealed anticancer properties of saporin-S6 by causing necrosis and apoptosis in pre-clinical models of various human cancer cells. Initially, these properties of saporin-S6 were considered due to the ability of these molecules to inhibit protein synthesis. However, many observations revealed that RIPs can also depurinate DNA and other nucleic acids. Saporin-S6 is able to kill cells via apoptosis (Bergamaschi et al., 1996; Bolognesi et al., 1996). Saporin-S6 induces apoptosis in caspase-dependent manner in U937 cells through a mitochondrial cascade, independently of translation inhibition. These proteins induce apoptosis via activation of caspase 9. Extrinsic pathway of apoptosis is not involved in saporin-S6-induced mediated apoptosis of U937 cells because caspase 8 and truncated Bid are not activated in this process (Sikriwal et al., 2008), while, in the case of L540 lymphoma cells, both caspase 9 and 8 are activated by saporin-S6 (Polito, et al., 2009). In the U87 glioblastoma cell line saporin-S6 treatment leads the activate ERK 1/2 (mitogen activated protein kinase) instead of caspase 8 and 9. Activation of ERK1/2 might cause cell cycle arrest in G1 phase with a decrease in D1 cyclin levels and causes apoptosis (might be due to activation of p53) (Cimini et al., 2012; Polito et al., 2013).

Gilabert-Oriol et al. (2016) reported that saporin SO1861 from *S. officinalis* increases the cytotoxicity of saporin without affecting its enzymatic activity. It was also found when immunotoxin saporin-rituximab was applied in the cells (human B-cell Burkitt lymphoma cells) with nontoxic concentration of the SO1861 the cytotoxicity increases to 700fold. Combinatorial use of SO1861 augments therapeutic potential of Rituximab-immunotoxins against B-cell lymphoma. SO1861 does so, by modifying trafficking of immunotoxins and inhibiting their degradation in lysosome and consequently increase their concentration in cytosol to inactivate ribosomes. Due to inactivation of ribosomes, protein synthesis stops and cell enter for apoptosis (Gilabert-Oriol et al., 2016).

**Antioxidant properties**

Lipid peroxidation is described as a process under which oxidants (free radicals or non radicals) attack lipids containing carbon double bonds. Consequent abstraction of hydrogen from carbon and insertion of oxygen form lipid free radicals and hydroperoxides. Membrane phospholipids are major targets of oxidative damage; hence lipid peroxidation is often the first parameter analysed for proving the involvement of free radical damage. Malondialdehyde (MDA) is one of the products of lipid peroxidation and it is widely used as marker for lipid peroxidation. MDA is the most mutagenic product of lipid peroxidation and can react with proteins and DNA (Ayal et al., 2014). Furthermore, presence of MDA is considered as an indicator of free-
radical damage through membrane lipid peroxidation. Antioxidant activity of *Saponaria officinalis* was observed in X rays irradiated rats and found that 100 mg/kg extract markedly depressed the oxidant concentrations by 20.8% on day 21 and by 30.6% on day 42. Consequently, the plasma MDA concentrations decreased in X rays irradiated rats treated with the plant extract (Kucukkurt et al., 2011). Plant extract exhibited directly reduce basal MDA formation and show antioxidant properties towards ionizing radiation-induced cell damage. Increase percentages of the antioxidant activity in plant extract treated rats marked with increases in the circulating vitamin C concentrations compared to the only irradiated controls. However, Deger et al. (2003) found that vitamins C and vitamins E do not affect initial values of MDA concentrations in rabbits after exposure to X-rays. Decreases in MDA concentrations in *Saponaria officinalis* treated rats could be due to the ability of extract to scavenge secondary reactive radicals and prevent formation of superoxide, hydrogen peroxide in response to the radiation treatment (Kucukkurt et al., 2011).

Antioxidant activity of the methanol extracts of *Saponaria officinalis* was determined according to the β-carotene bleaching method by Sengul et al. (2011). The results pointed that plant extract showed antioxidant activity (70.00%) which was less than standard Butylated hydroxyanisole (BHA) (93.21%) and Butylated hydroxytoluene (BHT) (90.71%). There is strong relationship between the total phenolic content and antioxidant activity in certain plants. In the *Saponaria officinalis* the phenolic content is 6.57 μg gallic acid equivalent (GAE)/mg, reported by Sengul et al. (2011).

**Anti-microbial properties**

Methanol extract of *S. officinalis* exhibit antimicrobial properties against *Bacillus subtilis*, *Staphylococcus aureus*, *Salmonella typhimurium*, *Candida albicans*, *Streptococcus thermophilus*, *Pseudomonas aeruginosa*, *Klebsiella pneumonia* subsp. *pneumonia*, *Staphylococcus hominis*, *Enterobacter cloacae*, *Escherichia coli*, *Proteus mirabilis*, *Klebsiella pneumonia* subsp. *ozanae*, *Providencia alcaliaciens*, *Acinetobacter lwoffi*, *Pseudomonas fluorescens*, *Pseudomonas putida*, *Yersinia enterocolitica* and *Penicillium brevicompactum*, while, aqueous of the plant exhibited antimicrobial activities against *Flavobacterium indologenes* (Sengul et al., 2011). The root extract of *S. officinalis* shows antifungal activities against *Candida albicans* (Sadowska et al., 2014). Exact mechanism of anti-microbial properties is not yet known but, it is postulated that saponins play an important role as ant-microbial compounds (Nabinejad, 2013).

**Other miscellaneous properties**

The hepatoprotective effect of *S. officinalis* roots was evaluated on mice model. The study revealed that the soapworts supplementation reduced the damaging effects on the liver by carbon tetrachloride (CCl₄). Exact mechanism of this property is yet not elucidated, but it is postulated that CCl₄ harm liver functioning by enhancing lipid peroxidation. Thus, root extract of *S. officinalis* might detoxify the free radicals produced following CCl₄ intoxication and enhance liver functioning (Rahman and Megeid, 2006). The saponin rich extract of *S. officinalis* probably do not remove lipids from the outer most layer of human skin epidermis (stratum corneum) (Jurek et al., 2019). *Tetranychus urticae* Koch, a two-spotted spider mite is one of the most harmful pests. It is phytophagous, feeds on field crops and greenhouse ornamentals including more than 1100 plant species. In greenhouse-grown plants, 30-gram root extract of *S. officinalis* in 1 litre water for about 25 min significantly reduce all developmental stages of the two spotted spider mites (Pavela, 2017; Pavela et al., 2017).

**Conclusions**

*Saponaria officinalis* is an important medicinal and ornamental plant. Different saporins found in the species cause cytotoxicity of various cell lines and thereby play an important role in cancer treatment. Various
kinds of saponins are synthesized by the species and exhibit anticancer, antimicrobial, antioxidant and anti-insecticide properties. Further studies need to be done for anticancer properties of the saponins and saporins of the species for proper understanding of their target-receptor mechanism and scientific evaluation of traditional medicinal uses.

**Authors’ Contributions**

SC: hypothesized and drafted the manuscript. DSR: guided drafting of the manuscript. AB: helped in the drafting. All authors read and approved the final manuscript.

**Acknowledgements**

This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

**Conflict of Interests**

The authors declare that there are no conflicts of interest related to this article.

**References**

Abdel-Rahman MK, Abd El-Megeid AA (2006). Hepatoprotective effect of soapworts (Saponaria officinalis), pomegranate peel (Punica granatum L) and cloves (Syzygium aromaticum linn) on mice with CCl4 hepatic intoxication. World Journal of Chemistry 1(1):41-46.

Agelet A, Bonet MÀ, Vallés J (2000). Home gardens and their role as a main source of medicinal plants in mountain regions of Catalonia (Iberian Peninsula). Economic Botany 54(3):295-309. [https://doi.org/10.1007/BF02864783](https://doi.org/10.1007/BF02864783)

Arora D, Sharma A (2012). Pharmacognostic and phytochemical studies of Stellaria media Linn. Journal of Pharmaceutical Sciences and Research 4(5):1819.

Ayala A. Munoz MF, Arguelles S (2014). Lipid peroxidation: Production, metabolism and signalling mechanism of Malondialdehyde and 4-hydroxy2-nonenal. Oxidative Medicine and Cellular Longevity [https://doi.org/10.1155/2014/360438](https://doi.org/10.1155/2014/360438)

Ballero M, Poli F, Sacchetti G, Loi MC (2001). Ethnobotanical research in the territory of Fluminimaggiore (south-western Sardinia). Fitoterapia 72(7):788-801. [https://doi.org/10.1016/s0367-326x(01)00334-3](https://doi.org/10.1016/s0367-326x(01)00334-3)

Bergamaschi G, Perfetti V, Tonon L, Novella A, Lucotti C, Danova M, ... Cazzola M (1996). Saporin, a ribosome-inactivating protein used to prepare immunotoxins, induces cell death via apoptosis. British Journal of Haematology 93:789-794. [https://doi.org/10.1046/j.1365-2141.1996.d01-1730.x](https://doi.org/10.1046/j.1365-2141.1996.d01-1730.x)

Bittirich V (1993). Introduction to Centrospermae. In: Kubitzki K, Rohwer JG, Bittrich V (Eds). The families and genera of vascular plants. Volume 2, Magnoliid, Hamamelid, and Caryophyllid families. Germany, Springer Science pp 206-236.

Bolognesi A, Tazzari PL, Olivieri F, Polito L, Falini B, Stirpe F (1996). Induction of apoptosis by ribosome-inactivating proteins and related immunotoxins. International Journal of Cancer 68:349-355. [https://doi.org/10.1002/(SICI)1097-0215](https://doi.org/10.1002/(SICI)1097-0215)

Bortger S, Melzig MF (2011). Triterpenoid saponins of the Caryophyllaceae and Illecebraceae family. Phytochemistry Letters 4:59-68. [https://doi.org/10.1016/j.phytol.2010.08.003](https://doi.org/10.1016/j.phytol.2010.08.003)

Chandra S, Rawat D, Chandra D, Rastogi J (2016). Nativity, phytochemistry, ethnobotany and pharmacology of Dianthus caryophyllus. Research Journal of Medicinal Plant 10(1):1-9. [https://doi.org/10.3923/rjmp.2016.1.9](https://doi.org/10.3923/rjmp.2016.1.9)
Chandra S, Rawat DS (2015). Medicinal plants of the family Caryophyllaceae: a review of ethno-medicinal uses and pharmacological properties. Integrative Medicine Research 4(3):123-131. https://doi.org/10.1016/j.imr.2015.06.004

Cimini A, Mei S, Benedetti E, Laurenti G, Koutris I, Cinque B, ... Di Leandro L (2012). Distinct cellular responses induced by saporin and a transferrin-saporin conjugate in two different human glioblastoma cell lines. Journal of Cellular Physiology 227:939-951. https://doi.org/10.1002/jcp.22805

Davis SL, Duddle DA, Nawrocki JR, Freestone LM, Konieczny P, Tobin MB, Britton MM (2014). Sexual dimorphism of staminate- and pistillate-phase flowers of Saponaria officinalis (Bouncing Bet) affects pollinator behavior and seed set. PLoS One 9(4):e93615. https://doi.org/10.1371/journal.pone.0093615

Deger Y, Dedê S, Belge A, Mert N, Kahraman T, Alkan M (2003). Effect of X-rays radiation on lipid peroxidation and antioxidant systems in rabbits treated with antioxidant compound. Biological Trace Element Research 94:149-156. https://doi.org/10.1385/BTER:94:2:149

Di Cola A, Di Domenico C, Poma A, Spano L (1997). Saporin production from in vitro cultures of the soapwort Saponaria officinalis L. Plant Cell Reports 17(1):55-59. https://doi.org/10.1007/s002990050351

El Aziz MMA, Ashour AS, Melad ASG (2019). A review on saponins from medicinal plants: chemistry, isolation, and determination. Nanomedicine Research Journal 7(4):282-288. https://doi.org/10.15406/njr.2019.07.00199

Ferreras J, Barbieri L, Girbès T, Bartelli M G, Rojo M A, Arias F J, Stirpe F (1993). Distribution and properties of major ribosome-inactivating proteins (28 S rRNA N-glycosidases) of the plant Saponaria officinalis L. (Caryophyllaceae). Biochimica et Biophysica Acta (BBA)-Gene Structure and Expression 1216(1):31-42. https://doi.org/10.1016/0167-4781(93)90034-B

Gilabert-Oriol R, Thakur M, Haussmann K, Niesler N, Bhargava C, Görick C, Weng A (2016). Saponins from Saponaria officinalis L. augment the efficacy of a rituximab-immunotoxin. Planta Medica 82(18):1525-1531. https://doi.org/10.1055/s-0042-110495

Girbès T, Ferreras JM, Arias FJ, Stirpe F (2004). Description, distribution, activity and phylogenetic relationship of ribosome-inactivating proteins in plants, fungi and bacteria. Mini Reviews in Medicinal Chemistry 4(5):461-476. https://doi.org/10.2174/1389557043403891

Greenberg AK, Donoghue MJ (2011). Molecular systematics and character evolution in Caryophyllaceae. Taxon 60(6):1637-1652.

Guarrera PM (1999). Traditional antihelmintic, antiparasitic and repellent uses of plants in Central Italy. The Journal of Ethnopharmacology 68(1-3):183-192. https://doi.org/10.1016/s0378-8741(99)00089-6

Hanlidou E, Karousou R, Kleftoyanni V, Kokkini S (2004). The herbal market of Thessaloniki (N Greece) and its relation to the ethnobotanical tradition. The Journal of Ethnopharmacology 91(2-3):281-299. https://doi.org/10.1016/j.jep.2004.01.007

Ho MC, Sturm MB, Almo SC, Schramm VL (2009). Transition state analogues in structures of ricin and saporin ribosome-inactivating proteins. PNAS 106(48):20276-20281. https://doi.org/10.1073_pnas.0911606106

Jabbari SG, Davis SL, Carter EJ (2012). Interaction between floral color change and gender transition in the protandrous weed Saponaria officinalis. Plant Species Biology https://doi.org/10.1111/j.1442-1984.2011.00352.x

Jia Z, Koike K, Nikaido T (1998). Major triterpenoid saponins from Saponaria officinalis. Journal of Natural Products 61:1368-1373. https://doi.org/10.1021/np980167a

Jia Z, Koike K, Nikaido T (1999). Major triterpenoid saponins from Saponaria officinalis. Journal of Natural Products 62:1655-1659. https://doi.org/10.1021/np990311r
Korkmaz M, Özçelik H (2011). Economic importance of Gypsophila L., Ankyropetalum Fenzl and Saponaria L. (Caryophyllaceae) taxa of Turkey. African Journal of Biotechnology 10(47):9533-9541. https://doi.org/10.5897/AJB10.2500

Kucukkurt I, Ince S, Enginar H, Eryavuz A, Fidan AF, Kargioglu M (2011) Protective effects of Agrostemma githago L. and Saponaria officinalis L. extracts against ionizing radiation-induced oxidative damage in rats. Revue de Médecine Vétérinaire 162 (6):289-296.

Loi MC, Poli F, Sacchetti G, Selenu MB, Ballero M (2004). Ethnopharmacology of Ogliastra (Villagrande strisaili, Sardinia, Italy). Fitoterapia 75(3-4):277-295. https://doi.org/10.1016/j.fitote.2004.01.008

Mamadalieva NZ, Lafont R, Wink M (2014). Diversity of secondary metabolites in the genus Silene L. (Caryophyllaceae)-structures, distribution, and biological properties. Diversity 6(3):415-499.

Man S, Gao W, Zhang Y, Huang L, Liu C (2010). Chemi cal study and medical application of saponins as anti-cancer agents. Fitoterapia 71(3):278-307. https://doi.org/10.1016/j.fitote.2010.06.004

Medeiros MFT, de Albuquerque UP (2012). The pharmacy of the Benedictine monks: The use of medicinal plants in Northeast Brazil during the nineteenth century (1823-1829). Journal of Ethnopharmacology 139(1):280-286. https://doi.org/10.1016/j.jep.2011.11.014

Moniuszko-Szajwaj B, Pecio Ł, Kowalczyk M, Simonet AM, Macias FA, Szumacher-Strabel M, Stochmal A (2013) New triterpenoid saponins from the roots of Saponaria officinalis. Natural Product Communications 8(12).

Nabinejad A (2013). Antibacterial effects of Saponaria officinalis extracts against avail pathogenic Escherichia coli. African Journal of Agriculture Research 8(8):2068-2071. https://doi.org/10.5897/AJAR11.1390

Novella R, Di Novella N, De Martino L, Mancini E, De Feo V (2013). Traditional plant use in the national park of Cilento and Vallo Di Diano, Campania, Southern, Italy. Journal of Ethnopharmacology 145(1):328-342. https://doi.org/10.1016/j.jep.2012.10.065

Pavela R (2017). Extract from the roots of Saponaria officinalis as a potential acaricide against Tetranychus urticae. Journal of Pest Science 90(2):683-692. https://doi.org/10.1007/s10340-016-0828-6

Pavela R, Murugan K, Canale A, Benelli G (2017). Saponaria officinalis-synthesized silver nanocrystals as effective biopesticides and oviposition inhibitors against Tetranychus urticae Koch. Industrial Crops and Products 97:338-344. https://doi.org/10.1016/j.indcrop.2016.12.046

Polito L, Bortolotti M, Farini V, Battelli MG, Barbieri L, Bolognesi A (2009). Saporin induces multiple death pathways in lymphoma cells with different intensity and timing as compared to ricin. International Journal of Biochemistry & Cell Biology 41:1055-1061.

Polito L, Bortolotti M, Mercatelli D, Battelli MG, Bolognesi A (2013). Saporin-S6: A useful tool in cancer therapy. Toxins 5:1698-1722. https://doi.org/10.3390/toxins5101698

POWO (2019a). Plants of the world online. Facilitated by the Royal Botanic Gardens, Kew. Retrieved 2020 March 25 from http://www.plantsoftheworldonline.org/

POWO (2019b). Plants of the world online. Facilitated by the Royal Botanic Gardens, Kew. Retrieved 2020 December 25 from http://www.plantsoftheworldonline.org/taxon/urn:lsid:ipni.org:names:156627-1#sources

Rahimi S, Kim J, Mijakovic I, Jung K, Choi G, Kim SC, Kim YJ (2019). Triterpenoid-biosynthetic UDP-glycosyltransferases from plants. Biotechnology Advances https://doi.org/10.1016/j.biotechadv.2019.04.016

Sadowska B, Budzynska A, Wie M, Szakiel C, Paskiewicz M, Stochmal A, ... Rozalska B (2014). New pharmacological properties of Medicago sativa and Saponaria officinalis saponin-rich fractions addressed to Candida albicans. Journal of Medical Microbiology 63:1076-1086. https://doi.org/10.1099/jmm.0.075291-0
Said O, Khalil K, Fulder S, Azaizeh H (2002). Ethnomedical survey of medicinal herbs in Israel, the Golan Heights and the West Bank region. Journal of Ethnomedical 83(3):251-265. https://doi.org/10.1016/s0378-8741(02)00253-2

Savino C, Federici L, Ippoliti R, Lendaro E, Tsernoglou D (2000). The crystal structure of saporin SO6 from Saponaria officinalis and its interaction with the ribosome. FEBS Letters 470(3):239-243. https://doi.org/10.1016/s0014-5793(00)01325-9

Sengul M, Ercisli S, Yildiz H, Gungo N, Kavaz A, Cetin B (2011). Antioxidant, antimicrobial activity and total phenolic content within the aerial parts of Artemisia absinthum, Artemisia santonicum and Saponaria officinalis. Iranian Journal of Pharmaceutical Research 10(1):49-56.

Shan-Huah W, Sun HT, Teng YC, Rejmánek M, Chaw SM, Yang TYA, Hsieh CF (2010). Patterns of plant invasions in China: taxonomic, biogeographic, climatic approaches and anthropogenic effects. Biological Invasions 12(7):2179-2206. https://doi.org/10.1007/s10530-009-9620-3

Sikriwal D, Ghosh P, Batra JK (2008). Ribosome inactivating protein saporin induces apoptosis through mitochondrial cascade, independent of translation inhibition. The International Journal of Biochemistry & Cell Biology 40:2880-2888. https://doi.org/10.1016/j.biocel.2008.06.004

Smulek W, Zdarta A, Pacholak A, Zgola-Grześkowiak A, Marczak Ł, Jarzębski M, Kaczorek E (2017). Saponaria officinalis L. extract: Surface active properties and impact on environmental bacterial strains. Colloids and Surfaces B: Biointerfaces 150:209-215. https://doi.org/10.1016/j.colsurfb.2016.11.035

Sparg SG, ME Light, van Staden J (2004). Biological activities and distribution of plant saponins. The Journal of Ethnomedical 94:219-243. https://doi.org/10.1016/j.jep.2004.05.016

Stearn WT (1983). Botanical Latin. David & Charles, London pp 566.

Stirpe F (2004). Ribosome-inactivating proteins. Toxicon 44:371-383. https://doi.org/10.1016/j.toxicon.2004.05.004

Stirpe F (2013). Ribosome-inactivating proteins: from toxins to useful proteins. Toxicon 67:12-16. https://doi.org/10.1016/j.toxicon.2013.02.005

Ugulu I, Baslar S, Yorek N, Dogan Y (2009). The investigation and quantitative ethnomedical evaluation of medicinal plants used around Izmir province, Turkey. Journal of Medicinal Plants Research 3(5):345-367.

Vincken JP, Heng L, Groot A de, Gruppen H (2007) Saponins, classification and occurrence in the plant kingdom. Phytochemistry 68:275-297. https://doi.org/10.1016/j.phytochem.2006.10.008

The journal offers free, immediate, and unrestricted access to peer-reviewed research and scholarly work. Users are allowed to read, download, copy, distribute, print, search, or link to the full texts of the articles, or use them for any other lawful purpose, without asking prior permission from the publisher or the author.

License - Articles published in Notulae Scientiae Biologicae are Open-Access, distributed under the terms and conditions of the Creative Commons Attribution (CC BY 4.0) License.

© Articles by the authors; SHST, Cluj-Napoca, Romania. The journal allows the author(s) to hold the copyright/to retain publishing rights without restriction.