Ethnobotany and Chemistry of Selected Plants in the Rutaceae Family

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KEYWORDS

Rutaceae; Ethnomedicinal Materials; Phytochemicals; Alkaloids; Phenols

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ABSTRACT

Plants in the Rutaceae family are widely distributed across the globe. They are important sources of ethnomedicinal materials and also rich in phytochemicals. This work focuses on some of the ethnobotanical uses and phytochemical composition of four (4) plant species belonging to the Rutaceae family, viz: Sweet Orange (Citrus sinensis L. Osbeck), Persian Lime (Citrus latifolia Yu. Tanaka), Tangerine (Citrus tangerina Tanaka) and Lemon (Citrus limon (L.) Osbeck). It was revealed that different parts of the plants have been found useful in curing and managing ailments such as infertility, cancer, diabetes mellitus, and cholera among others. Important chemicals including but not limited to alkaloids, carotenoids, flavonoids, tannins, phenols, and terpenoids have also been identified in the plants. Similar review should be carried out on other taxonomic families so that there would be comprehensive documentation of the ethnobotanical relevance and phytochemical constituents of many plant families.

INTRODUCTION

The history of medicinal plants goes back thousands of years when ancient cultures used plants to treat a wide range of illnesses, some of which are still used today (Yuan *et al*., 2016; Salmerón-Manzano *et al*., 2020). Many traditional remedies have been passed down through generations and continue to be used in some parts of the world (Che *et al*., 2017). In recent times, modern science has begun to explore the potential of medicinal plants and their active compounds.

The chemistry of medicinal plants has been studied extensively by many researchers and has revealed a variety of compounds that can be used to treat a range of medical conditions (Altemimi *et al*., 2017). These compounds can be found in a variety of plants, from herbs and shrubs to trees and vines. The chemical compounds vary from plant to plant, but they all have the potential to be used as treatments. In addition to the active compounds, some plants also contain other beneficial compounds such as antioxidants, anti-inflammatories, and other bioactive molecules that can be used to treat a range of medical conditions (Suffredini *et al*., 2004). The combination of ethnobotany and chemistry brings together the traditional knowledge of medicinal plants and the scientific knowledge of their active compounds (Heredia *et al*., 2022). This combination can be used to develop new treatments and to improve existing treatments. Ethnobotany can provide insight into the traditional uses of medicinal plants (Wanjohi *et al*., 2020) and the chemistry of medicinal plants can reveal the active compounds that can be used to treat various medical conditions (Egbuna *et al*., 2020).

The chemistry of plants is enshrined in the metabolites or organic compounds synthesized by the plants. These metabolites, also called phytochemicals are responsible for the medicinal effects these plants have on their users. The components of the chemicals found in certain plants are a major factor in their individual species' special characteristics and medicinal qualities, which is why they are used widely in medical practice (Lovkova *et al*., 2001). It is common knowledge that all plants produce chemicals that give them certain advantages such as defense, growth, and pollinator attraction, to mention a few (*Hayat and Ahmad, 2007). Some of these chemicals have potential use in drug production. For instance,* quinine *is a compound obtained from Cinchona succirubra and has been found effective in treating malaria (Willcox, 2004).*

Due to the diverse forms and structures of phytochemicals, their exact classifications are not universal (Deepak *et al*., 2016). However, a broad classification put them into primary and secondary metabolites, depending on the roles they play in plant metabolism (Ramawat *et al*., 2009). Primary metabolites include but are not limited to carbohydrates, lipids, proteins, amino acids, and nucleic acids, while secondary metabolites are the other plant chemicals such as alkaloids, terpenoids, and phenolics which do not serve principal functions in the plant (Hahn, 1998).

Ethnobotany

The word ethnobotany is derived from two different words, *ethno*- (ethnic) which means culture, race or people and *botany* which comes from the Greek word *botanē* meaning herbs, pasture or grass (Chavda *et al*., 2022). Hence, ethnobotany can be described as the utilization of herbs in different cultures. The term “ethnobotany” was first used in 1895 by the botanist, John, W. Harsherberg who defined it as “the use of plants by primitive and aboriginal peoples” (Serge and Claire, 2018). Several other definitions have been given to the term by different authors. According to Vokes (2017), “ethnobotany is the study of the dynamic relationship between plants and people”. The United State Department of Agriculture (USDA, 2008) defined ethnobotany as “the study of how people of a particular culture and region make use of indigenous (native) plants”. Ethnobotany is a distinct field of research yet with a strong multidisciplinary outlook (Schultes, 2016). Several researchers over the years have attempted to highlight the multidisciplinary nature of ethnobotany. Suthari *et al*. (2021) underscored the prominent utility patterns of ethnobotany in various disciplines of science (Figure 1).

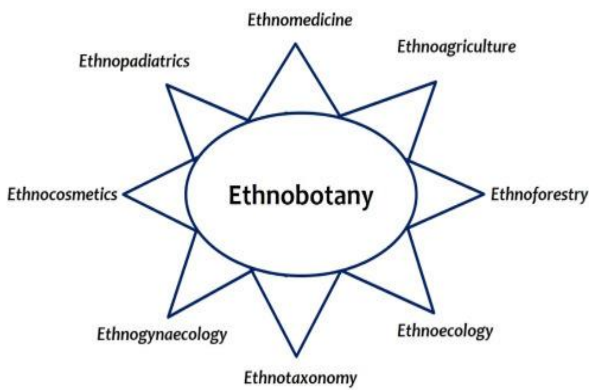


Figure 1: Major utility patterns of ethnobotany in different science disciplines (Suthari *et al*., 2021).

Chemistry

Chemistry is a broad field that a single definition may not capture its scope. Brown *et al*. (2018) described chemistry as the scientific study of the properties and behaviour of matter. The Merriam-Webster dictionary explained chemistry as “a science that deals with the composition, structure, and properties of substances and with the transformations that they undergo.” Chemistry addresses concepts such as matter, atoms, molecules, elements, compounds, ions, and chemical bonds to mention a few. It is no exaggeration that no part of our day-to-day life is devoid of one chemical activity or the other. We find chemistry in our food, drink, clothing, gadgets, buildings, and a host of other things.

In the context of ethnobotany, chemistry studies the composition of plants, especially medicinal plants. Hence, chemistry becomes relevant in the study of ethnobotany as it deals with chemicals (phytochemicals) produced by plants. This is referred to as phytochemistry. “Phytochemistry considers the structural compositions of plant metabolites, the biosynthetic pathways, functions, mechanisms of actions in the living systems as well as its medicinal, industrial, and commercial applications” (Egbuna *et al*., 2020). Phytochemicals have great antioxidant properties and are of great interest due to their valuable effects on human health, and they give enormous health benefits to consumers (Thakur *et al*., 2020).

There is no universally agreed classification of phytochemicals because there are tens of thousands of them that have been discovered. However, Egbuna *et al*. (2020) classified them into phenolics, terpenes, terpenoids, N-, and S-containing compounds.

Table 1: Classification of common phytochemicals

Major class	Subclasses	Representatives
Phenolics	Polyphenols	Flavonoids, isoflavonoids, chalconoids, lignans, stilbenoids (e.g., resveratrol), curcuminoids, and tannins (e.g., protocatechuic and chlorogenic acids).
	Aromatic acid	Phenolic acids (e.g., gallic acid, tannic acid, vanillin, ellagic acid), hydroxycinnamic acids (e.g., coumarin)
Terpenes	Monoterpenes	Geraniol, limonene, pyrethroids, myrcene
	Sesquiterpenes	Costunolides
	Diterpenes	Abietic acid, cafestol, gibberellins
	Triterpenes	Azadirachtin, phytoecdysones
	Polyterpenes	Tetraterpenes, for example, carotenoids, rubber
Terpenoids	Carotenoids (tetraterpenoids)	β-carotene, lycopene, phytoene
	Xanthophylls	Lutein, zeaxanthin
	Triterpenoid	Saponins, ursolic acid
	Steroids	Tocopherols (vitamin E), phytosterols (β-sitosterol, campesterol)
N (organonitrides)	Alkaloids	Nicotine, morphine, caffeine, theobromine, theophylline
	Cyanogenic glucosides	
	Nonprotein amino acids	Canavanine, azetidine-2-carboxylic acid
S (organosulfides)	Allicin, alliin, piperine	
	Glutathione, phytoalexins	
Others	Phytic acid, oxalic acid, tartaric acid, malic acid, quinic acid	

Source: Egbuna *et al.* (2020)

Rutaceae

Rutaceae is a family of flowering plants that includes shrubs and trees in the order Sapindales (Appelhans *et al*., 2021). The family is commonly referred to as the citrus family. The Rutacea family is widespread and highly diverse, with about 2100 species in 154 genera (Kubitzki *et al*., 2011). The family is found in tropical and subtropical regions, with a few species occurring in temperate climates (Appelhans *et al*., 2021). The leaves of plants in the Rutaceae family are typically opposite or alternate and are often pinnately or palmately compound (Brizicky, 1962). The flowers are small and typically have four or five petals and sepals (Brizicky, 1962). The family is best known for its citrus fruits, which include oranges, lemons, limes, and grapefruits. Other important members of the family include the rutas, or rue plants, which have a long history of medicinal use, and the euodias, which produce an essential oil used in perfumes. The taxonomic hierarchy of the Rutaceae family is shown in Table 2. The selected plants in the Rutacea family for this study are Sweet Orange (*Citrus sinensis* L. Osbeck), Persian Lime (*Citrus latifolia* Yu. Tanaka), Tangerine (*Citrus tangerina* Tanaka) and Lemon (*Citrus limon* (L.) Osbeck) (Plate 1-4).

Table 2: Taxonomic hierarchy of Rutaceae family

Kingdom	**Plantae – plantes, Planta, Vegetal, plants**
Subkingdom	Vindiplantae – green plants
Infrakingdom	Streptophyta – land plants
Superdivision	Embryophyta
Division	Tracheophyta – vascular plants, tracheophytes
Subdivision	Spermatophytina – spermatophytes, seed plants, phanerogames
Class	Magnoliopsida
Superorder	Rosanae
Order	Sapindales
Family	Rutaceae – rues, rutacees

Source: Integrated Taxonomic Information System

Plate 1: Sweet Orange (Citrus sinensis L. Osbeck) (Source: https://pfaf.org/)

Plate 2: Persian Lime (Citrus latifolia Yu. Tanaka) (Source: Grayum, 2012)

Plate 3: Tangerine (Citrus tangerina Tanaka) (Source: https://www.needpix.com/)

Plate 4: Lemon (*Citrus limon* (L.) Osbeck) (Source: Royal Botanical Gardens Kew)

Ethnobotany and Chemistry of Selected Plants in the Rutaceae Family

The ethnobotanical uses of the selected plants in the citrus family have been documented in the literature. Some of the uses are summarized in Table 3.

Table 3: Ethnobotany and phytochemical constituents of selected plants in the Rutaceae family

Plant	Disease treated	Plant part used	Method of preparation and use	Phytochemical constituents	Reference
Citrus sinensis	Infertility in human	Juice	Stem of *Xylopia aethiopica*, fruit of *Citrullus colocynthis* and leaves of *Lagenaria breviflora* is dried and grinded and mixed with the juice of sweet orange. One teaspoonful to be taken orally every morning for 9 days.	Alkaloids, amino acids, carbohydrates, carotenoids, flavonoids, steroids, tannins, phenols, terpenoids	Okwu, 2008; Chede, 2012; Mathew *et al*., 2012; Soladoye *et al*., 2014; Oikeh *et al*., 2015; Chaudhari *et al*., 2016; Lawal and Olagoke; 2016; Roghini and Vijayalakshmi, 2018; Khandla *et al*., 2020.
	Citrus sinensis has also been used to treat arthritis, asthma, Alzheimer's disease, cholera, macular degeneration, gallstones, multiple sclerosis, gingivitis, Parkinson's disease, diabetes mellitus, cataracts, ulcerative colitis, and Crohn's disease. The peel is also used as mosquito repellents in many local communities.				

Citrus latifolia	Cancer in human	Juice	Root of *Calliandra haematocephalaare*, bark of *Bridellia ferruginea*, bark *Mangifera indica*, bark of *Tricalysia macrophylla*, bark of *Antiaris africana*, bark of *Trichilia monadalpha*, leaves of *Allium ascalonicum* and bark of *Nauclea latifolia* rinsed and boiled in water for 40 minutes. Lime juice is added when cooled and it is taken three times daily for 2 months	Alkaloids, amino acids, carbohydrate, carotenoids, flavonoids, steroids, tannins, phenols, saponins, terpenoids	Aiyeloja and Bello, 2006; Okwu, 2008; Soladoye *et al*., 2010; Chede, 2012; Mathew *et al*., 2012; Oikeh *et al*., 2015; Chaudhari *et al*., 2016; Roghini and Vijayalakshmi, 2018; Khandla *et al*., 2020.
		Root	Seed of *Xylopia aethiopica*, seed of *Aframomum melegueta*, root of *Plumbago zeylanica* and root of lime should be ground together smoothly and mixed with black soap and gun powder. Use the preparation to wash all the parts of the body, once a week		
Citrus tangerine	Citrus tangerine has been used as or in the management of diseases relating to the abdomen, aches, antidote, dysmenorrhea, anodyne, dyspepsia, panacea, antiseptic, bactericide, refrigerant, pectoral, bubo, diarrhea, breast cancer, stomach cancer, carminative, pimple, chest congestion, deobstruent, dyspnea, emmenagogue, freckle, fungicide, gas, prolapse, nausea, marasmus, rectocele, rib, sedative, sore, spasm, splenitis, stomach, stomachic, thirst, urogenital, uterus, vermifuge, wine-Nose.			Alkaloids, amino acids, carbohydrates, carotenoids, flavonoids, steroids, tannins, phenols, saponins, terpenoids	Aiyeloja and Bello, 2006; Okwu, 2008; Bibalani and Sayadmahaleh, 2011; Suryawanshi, 2011; Chede, 2012; Mathew *et al*., 2012; Oikeh *et al*., 2015; Chaudhari *et al*., 2016; Roghini and Vijayalakshmi, 2018; Khandla *et al*., 2020.
Citrus limon	Worm	Juice	Raw juice should be taken every day before the meal.	Alkaloids, amino acids, carbohydrates, carotenoids, flavonoids, steroids, tannins, phenols, saponins, terpenoids	Aiyeloja and Bello, 2006; Okwu, 2008; Soladoye *et al*., 2010; Chede, 2012; Mathew *et al*., 2012; Soladoye *et al*., 2014; Oikeh *et al*., 2015; Roghini and Vijayalakshmi, 2018; Khandla *et al*., 2020.
	Cancer in human	Juice	Leaves of *Nymphaea lotus*, leaves of *Pistia stratiotes*, crushed stem of *Saccharum offinarum*, bark of *Morinda lucida* and seed of *Xylopia aethiopica* are rinsed and boiled in 1L of lemon juice and palm oil for 3 hours. Two teaspoonful morning and night.		

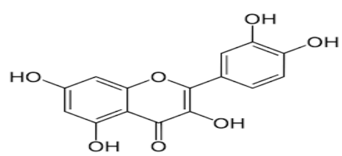
The phytochemical constituents of the plants and their abundance have also been documented. Table 4 presents the phytochemical composition of the plants.

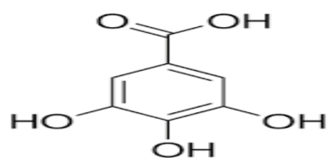
Table 4: Phytochemical constituents of selected plants in the Rutaceae family

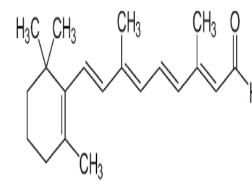
	Citrus sinensis		***Citrus latifolia***		***Citrus tangerina***		***Citrus limon***	
Phytochemicals	EE	AE	EE	AE	EE	AE	EE	AE
Alkaloids	+	+	+	+	++	*	++	++
Phenols	+	+	+	+	+	*	+	+
Flavonoids	+	+	+	+	+	*	+	+
Steroids	+	+	+	+	++	*	+	+
Terpenoids	+	-	+	+	++	*	+	+
Saponins	-	-	+	+	++	*	+	+
Reducing sugar	+	+	+	+	+	*	+	+
Tannins	+	+	+	+	+	*	+	+
Carbohydrate	+	+	+	+	++	*	+	+

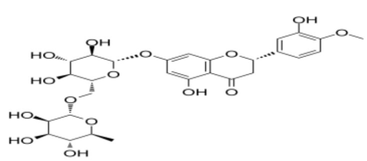
Source: Chede (2012); Mathew *et al*. (2012); Oikeh *et al*. (2015); Roghini and Vijayalakshmi (2018)
EE = ether extract; AE = aqueous extract; + = slightly present; ++ = highly present; - = absent; * = no reliable source to depend on

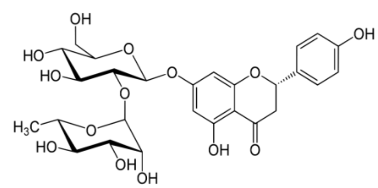
Literature (Okwu, 2008; Roghini and Vijayalakshmi, 2018; Khandla *et al*., 2020) has also shown some of the representatives of the major phytochemicals present in the selected plants. They are Quercetin, Gallic acid, Hesperidin, Naringin, Tangeritin, Rutin, Limonene, β-Carotene, Lycopene, Lutein, Zeaxanthin, and Retinal (Figure 2).

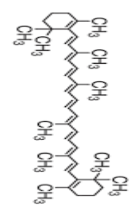

Quercetin

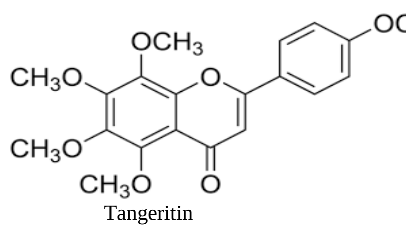

Gallic acid

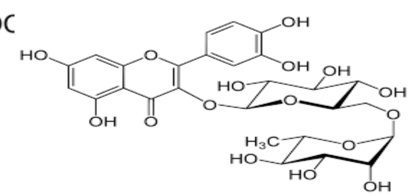

Retinal

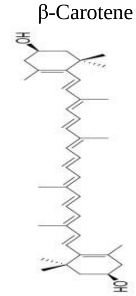

Hesperidin


Naringin


β-Carotene


Tangeritin


Rutin


Zeaxanthin

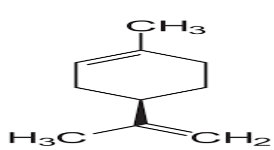

Limonene

Figure 2: Chemical structure of the representatives of the phytochemicals present in the selected plants

CONCLUSION

This work revealed that the Rutaceae family is an important taxonomic family whose members are ethnobotanically relevant and rich in phytochemicals. More of this documentation should be extended to other taxonomic families. In this modern world, it is not sufficient to know and understand what the local people use each plant species for, rather scientific backings are required to validate the claims, and this will be known by phytochemically screening the plant species.

REFERENCES

Aiyeloja A.A. and Bello, O.A. (2006). Ethnobotanical Potentials of Common Herbs in Nigeria: A Case Study of Enugu State. *Educational Research and Review* 1(1): 16-22.

Altemimi, A., Lakhssassi, N., Baharlouei, A., Watson, D.G. and Lightfoo, D.A. (2017). Phytochemicals: Extraction, Isolation, and Identification of Bioactive Compounds from Plant Extracts. *Plants* 6: 42.

Appelhans, M.S., Bayly, M.J., Heslewood, M.M., Groppo, M., Verboom, G.A., Forster, G.I., Kallunki, J.A. and Duretto, M.F. (2021). A New Subfamily Classification of the Citrus Family (Rutaceae) Based on Six Nuclear and Plastid Markers. *Taxon* 7(5): 1035-1061.

Bibalani, G.H. and Sayadmahaleh, F.M. (2011). Recognition And Consumption Uses and Medicinal Properties of Sour Orange (*Citrus aurantium*) by Rural People in East Part of Gilan Province (North Iran). *Journal of Medicinal Plants Research* 5(7): 1238-1243.

Brizickey, G.K. (1962). The Genera of Rutaceae in the Southeastern United States. *Journal of the Arnold Arboretum* 43(1): 1-22.

Brown, T.L., LeMay, H., Eugene, J., Bursten, B.E., Murphey, C.J., Woodward, P.M., Stoltzfus, M.W. and Lufaso, M.W. (2018). *Introduction: Matter, Energy, and Measurement*. Chemistry: The Central Science (14th ed.). New York: Pearson. pp. 46–85.

Chaudhari, S.Y., Ruknuddin, G. and Prajapati, P. (2016). Ethno Medicinal Values of Citrus Genus: A Review. *Medical Journal of Dr. D.Y. Patil University* 9: 560-565.

Chavda, N. Rathore, R. and Solank, H. (2022). An Overview of Historical Background of Ethnobotany and Indigenous Culture of India. *International Journal of Creative Research Thoughts* 10(4): 738-751.

Che, C.T., George, V., Ijinu, T.P., Pushpangadan, P. and Andrae-Marobela, K. (2017). Traditional Medicine. In *Pharmacognosy* Badal, S and Delgoda, R (eds). Academic Press. Pp. 15-30.

Chede, P.S. (2012). Phytochemical Analysis of Citrus sinensis Pulp. *International Journal of Pharmacognosy and Phytochemical Research* 4(4): 221-223.

Deepak, K. Rupali, S. and Mahesh, K. (2016). An Overview of Major Classes of Phytochemicals: Their Types and Role in Disease Prevention. *Hislopia Journal* 9 (1/2): 1-11.

Egbuna, C., Ifemeje, J.C., Kryeziu, T.L., Mukherjee, M., Shah, H., Narasimha, G.H., John, R.L., Gido, F.J. and Tijjani, H. (2020). Introduction to Phytochemistry. In *Phytochemistry Fundamentals, Modern Techniques and Applications* Egbuna, C., Ifemeje, J.C., Udedi, S.C and Kumar, S. (eds), Vol 1. Apple Academic Press. CRC Press, Taylor and Francis Group.

Grayum, M.H., Hammel, B.E. and Madrigal, J.Q. (2012). Validation of a Scientific Name for the Tahitian lime. *Phytoneuron* 101: 1-5.

Hahn, N.I. (1998). Is Phytoestrogens Nature's Cure for What Ails Us? A Look at the Research. *Journal of the American Dietetic Association* 98: 974-976.

Hayat, S. and Ahmad, A. (2007). Salicylic Acid – A Plant Hormone. Springer Science and Business Media. ISBN 978-1-4020-5183-8.

Heredia, D., Green, I., Klaasen, J. and Rahiman, F. (2022). Importance and Relevance of Phytochemicals Present in *Galenia Africana*. *Scientifica* 5793436.

Khandla, S.N., Vala, M.S. and Maitreya, B.B (2020). A Review: Phytochemical Constituents, Medicinal Uses and Economical Value of Orange Peels (*Citrus sinensis* L Osbeck). *International Journal of Creative Research Thoughts* 8(5): 1340-1354.

Kubitzki, K., Kallunki, J.A., Duretto. D. and Wilson, P.G. (2011). Rutaceae. In: *The Families and Genera of Vascular Plants* Kubitzki, K. (ed.). Springer, Berlin, Pp. 276-356.

Lawal, I.O and Olagoke, T.H. (2016). A Review on Anti-Malarial Activities of Selected Plant Species from the Rutaceae Family. *Journal of Pharmacognosy and Phytochemistry* 4(2): 1-6.

Lovkova, M.Y., Buzuk, G.N., Sokolova, S.M. and Kliment'eva, N.I. (2001). Chemical Features of Medicinal Plants (Review). *Applied Biochemistry and Microbiology* 37: 229-237.

Mathew, B.B., Jatawa, S.K. and Tiwari, A. (2012). Phytochemical Analysis of *Citrus Limonum* Pulp and Peel. *International Journal of Pharmacy and Pharmaceutical Sciences* 4(2): 369- 371.

Oikeh, E.I. Omoregie, E.S., Oviasogie, F.E. and Oriakhi, K. (2015). Phytochemical, Antimicrobial, and Antioxidant Activities of Different Citrus Juice Concentrate. *Food Science and Nutrition* 4(1): 103-109.

Okwu, D.E. (2008). Citrus Fruits: A Rich Source of Phytochemicals and Their Roles in Human Health. *International Journal of Chemical Science* 6(2): 451-471.

Ramawat, K.G., Dass, S. and Mathur, M. (2009). The Chemical Diversity of Bioactive Molecules and Therapeutic Potential of Medicinal Plants. In: *Herbal Drugs: Ethnomedicine to Modern Medicine*. Springer- Verlag Berlin Heidelberg.

Roghini, R. and Vijayalakshmi, K. (2018). Phytochemical Screening, Quantitative Analysis of Flavonoids and Minerals in Ethanolic Extract of *Citrus paradisi. International Journal of Pharmaceutical Sciences and Research* 9(11): 4859-4864.

Salmerón-Manzano, E., Garrido-Cardenas, J.A. and Manzano-Agugliaro, F. (2020). Worldwide Research Trends on Medicinal Plants. *International Journal of Environmental Research and Public Health* 17: 3376.

Schultes R.E. (2016). *Ethnobotany*. In: Selin, H. (eds) Encyclopaedia of the History of Science, Technology, and Medicine in Non-Western Cultures. Springer, Dordrecht.

Serge, M. and Claire, L. (2018). *Animal and Human Pharmacopoeias*. In Serge, M. and Claire, L (eds) Biodiversity and Health. Elsevier, pp. 103-117.

Soladoye, M.O., Amusa, N.A., Raji-Esan, S.O., Chukwuma, E.C. and Taiwo, A.A. (2010). Ethnobotanical Survey of Anti-Cancer Plants in Ogun State, Nigeria. *Annals of Biological Research* 1(4): 261-273.

Soladoye, M.O., Chukwuma, E.C., Sulaiman, O.M. and Feyisola, R.T. (2014). Ethnobotanical Survey of Plants Used in the Traditional Treatment of Female Infertility in Southwestern Nigeria. *Ethnobotany Research and Applications* 12: 81-90.

Suffredini, I.B., Sader, H.S., Gonçalves, A.G., Reis, A.O., Gales, A.C., Varella, A.D. and Younes, R.N. (2004). Screening of Antibacterial Extracts from Plants Native to the Brazilian Amazon Rain Forest and Atlantic Forest. *Brazilian Journal of Medical and Biological Research* 37: 379–384.

Suryawanshi, J.A.S. (2011). An Overview of *Citrus aurantium* Used in Treatment of Various Diseases. *African Journal of Plant Science* 5(7): 390-395.

Suthari, S., Kota, S., Kanneboyena, O., Gul, M.Z., and Abbagani, S. (2021). Ethnobotanical Perspectives in the Treatment of Communicable and Noncommunicable Diseases. In *Phytomedicine*. Elsevier. https://doi.org/10.1016/B978-0-12-824109-7.00016-9.

Thakur, M., Singh, K. and Khedkar, R. (2020). *Phytochemicals: Extraction Process, Safety Assessment, Toxicological Evaluations, and Regulatory Issues*. In Bhanu, P. (ed) Functional and Preservative Properties of Phytochemicals, Academic Press, pp. 341-361.

United States Department of Agriculture (USDA) (2008). https://www.fs.usda.gov/wildflowers/ethnobotany/index.shtml. Adapted on 27 November 2022.

Vokes, R. (2017). *Ethnobotany*. In Richardson, D., Castree, N., Michael, F. G, Kobayashi, A, Liu, W and Marston, R.A. (eds) The International Encyclopedia of Geography. John Wiley and Sons, Ltd.

Wanjohi, B.K., Sudoi, V., Njenga, E.W. and Kipkore, W.K. (2020). An Ethnobotanical Study of Traditional Knowledge and Uses of Medicinal Wild Plants among the Marakwet Community in Kenya. *Evidence-Based Complementary and Alternative Medicine* 3208634.

Willcox, M. (2004). *Traditional Medicinal Plants and Malaria. CRC Press. ISBN 9780203502327*.

Yuan, H., Ma, Q., Ye, L. and Piao, G. (2016). The Traditional Medicine and Modern Medicine from Natural Products. *Molecules* 21: 559.