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Par :

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Sur le thème

Enquêtes ethnobotaniques, phytochimiques et biologiques sur les plantes médicinales les plus courantes dans le Sud-Ouest Algérien.

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DEDICATION

To my Parent, Fateh & Fatiha

To my Husband, Mohammed

To my son, Tamim

To my brothers and sisters,

To all my close relatives,

With love and respect

Acknowledgments

I acknowledge your help Allah with gentle humility, without your guidance and love this work would not have been possible.

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ملـــخـــص

تم في هذا العمل إجراء دراسة اثنوصيدلانية لنباتات طبية من منطقة بشار، فضلا عن دراسات فيتوكيميائية وبيولوجية بما في ذلك الفعاليات المضادة للاكسدة، للبكتيريا وللفطريات لتسعة نباتات طبية فولكلورية، تستخدم على نطاق واسع في الطب التقليدي في جنوب غرب الجزائر.

أجريت الدراسة الاثنوصيدلانية بهدف جمع معلومات تفصيلية عن استخدامات النباتات الطبية في منطقة بشار، أين تم احصاء 162 نوعا من النباتات تمثلت في 143 جنسا و 50 عائلة نباتية. أكثر الفصائل استعمالا: النجمية (المركبة) (18 نبتة)، الخَيْمِيَّة و الشفوية (12 نبتة كل على حدى). كانت الأوراق الأكثر استعمالا كجزء من النبات. أما استخلاص بالاغلاء و اللبخات فكانتا أكثر الطرق شيوعا لإعداد الوصفات العلاجية التقليدية.

تم تقييم المحتوى النباتي وكذا الفاعلية المضادة للأكسدة والمضادة للميكروبات للمستخلصات المائية والهيدروميثانولية لتسعة نباتات طبية من منطقة بشار، ألا وهي: الاذخر، اللهاد، تسلغا، نوعان من نبات الرمث الأخضر و الأحمر، لحلاب، الجداري، الفرسيق وضمران. من بين كل المستخلصات، أظهر كل من المستخلص المائي لنبات الجداري (0.079±276.221 ملغ GAE/غ) والمستخلصات الهيدروميثانولية لنبتتي لحلاب و الرمث الأحمر (0.037±245.095 و 0.231±243.609 ملغ GAE/غ على التوالي) أعلى المحتويات الفينولية. كما أظهرت المستخلصات الهيدروميثانولية لنباتات لحلاب، جداري و تسلغا أعلى محتوى من الفلافونويدات (0.234±646.531، 0.023±510.531 و0.077±494.197 ملغ QE/غ على التوالي)، في حين أن المستخلصات الهيدروميثانولية لنباتات اللهاد، جداري و الرمث الأخضر أظهرت أعلى محتوى من السكاريدات (0.005±356.609، 0.049±350.440 و 0.046±344.957 ملغ GE/غ على التوالي).

فيما يخص الفعالية المضاد للأكسدة، فقد سجلت المستخلصات الهيدروميثانولية والمائية لنبات الجداري أعلى نشاط مضاد للأكسدة بـ IC_{50} منخفض جدا (15.838 و 19.539 ملغ/مل على التوالي). اما المستخلصات الهيدروميتانولية لنباتات الجداري، لحلاب، فرسيق و الرمث الأحمر فقد سجلت اعلى الفعاليات للحد من الأكسدة (0.294±624.194، 0.054±589.195، 0.141±470.423 و 0.153±436.914 AAEFRAP/غ على التوالي). في حين أن المستخلصات المائية والهيدروميتانولية لنبات جداري (0.1812±426.581 و0.326±361.507 ملغ AAE/غ على التوالي) والمستخلصات الهيدروميثانولية لنباتات فرسيق، الرمث الأحمر ولحلاب (0.165±295.166، 0.051±289.673 و0.170±264.108 ملغ AAE/غ على التوالي) فقد سجلت أعلى قدرة كلية مضادة للأكسدة.

تم تسجيل أقصى نشاط مضاد للبكتيريا ضد السلالات المرجعية سلبية الغرام الزائفة الزنجارية والإشريكية القولونية بأكبر قطر تثبيط قُدِّر بـــ 0.5±15.6 و 1.4±15.0 ملم على التوالي من قبل المستخلص المائي لنبات الفرسيق. كما اظهرت الدراسة ان المستخلص الهيدروميثانولي لنبات الجداري والمستخلص المائي لنبات اللهاد من افضل المستخلصات لتثبيط نمو الفطريات الخيطية من نوع الرشاشيات (77 و 66٪ على التوالي).

الكلمات المفتاحية:

النباتات طبية، دراسة اثنوصيدلانية، دراسة فيتوكيميائية، الفعالية المضادة للاكسدة، الفعالية المضادة للبكتيريا، الفعالية المضادة للفطريات، منطقة بشار، الجنوب الغربي الجزائري.

Abstract

An Ethnobotanical survey of medicinal plants from the Bechar region, as well as phytochemical, antioxidant, antibacterial, and antifungal studies of nine folkloric medicinal plants, widely used in traditional medicine in southwest Algeria, are being actively conducted in this work.

The Ethnobotanical survey was undertaken to collect detailed information about the usage of plants in human therapy in the Bechar region. A total of 162 plant species representing 143 genera and 50 families were used in the treatment of various diseases. The most encountered medicinal plant families were Asteraceae (18 spp.), Apiaceae & Lamiaceae (12 spp. each). Plant leaves were the most commonly used plant part. Whereas, decoction and cataplasm were the most common methods of traditional drug preparation.

The assessment of phytochemical content, antioxidant potency and antimicrobial activity of the crude aqueous and hydromethanolic extracts of a nine-folkloric medicinal plant from Bechar region (southwest Algeria), namely: *A. nardus*, *A. schoenanthus*, *G. alypum*, two species of *H. scoparia green* & *red*, *P. laevigata*, *R. tripartita*, *T. gallica*, and *T. nudatum*, was conducted.

Among all extracts, the aqueous extract of *R. tripartita* (276.221±0.079 mg GAE/g) and the hydromethanolic extracts of *P. laevigata* and *H. scoparia* red (245.095±0.037 and 243.609±0.231 mg GAE/g respectively) showed the highest phenolic content. The hydromethanolic extracts of *P. laevigata*, *R. tripartita*, and *G. alypum* showed the highest flavonoids content (646.531±0.234, 510.531±0.023, and 494.197±0.077 mg QE/g respectively), whereas, the hydromethanolic extracts of *A. schoenanthus*, *R. tripartita*, and *H. scoparia* green showed the highest polysaccharide content (356.609±0.005, 350.440±0.049 and 344.957±0.046 mg GE/g respectively).

The antioxidant activity performed by DPPH, FRAP, and TAC shows that the both extracts of *R. tripartita* exhibited the highest total antioxidant activity with a very low IC_{50} (15.838 and 19.539 mg/mL respectively). The hydromethanolic extracts of *R. tripartita*, *P. laevigata*, *T. gallica*, and *H. scoparia* red had the highest ferric reducing antioxidant potency (624.194±0.294, 589.195±0.054, 470.423±0.141, and 436.914±0.153 AAEFRAP/g respectively). Whereas, the aqueous and hydromethanolic extracts of *R. tripartita* (426.581±0.1812 and 361.507±0.326 mg AAE/g respectively) and the hydromethanolic extracts of *T. gallica*, *H. scoparia* red, and *P. laevigata* (295.166±0.165, 289.673±0.051, and 264.108±0.170 mg AAE/g respectively) had the highest total antioxidant capacity.

The maximum antibacterial activity was recorded against the gram-negative reference strains *Pseudomonas aeruginosa* and *Escherichia coli* with a maximum inhibition diameter of 15.6±0.5 and 15.0±1.4 mm respectively displayed by the aqueous extract of *T. gallica.*

The antifungal activity revealed that the hydromethanolic extract of *R. tripartita* and the aqueous extract of *T. nudatum* were the best to suppress the growth of *Aspergillus nidulans* (77 and 66% respectively).

Keywords:

Medicinal plants, ethnobotanical survey, phytochemical screening, antioxidant potency, antibacterial activity, antifungal activity, Bechar region, southwest Algeria.

Resumé

Une enquête ethnobotanique sur les plantes médicinales de la région de Bechar, ainsi que des études phytochimiques, antioxydantes, antibactériennes et antifongiques de neuf plantes médicinales folkloriques, largement utilisées dans la médecine traditionnelle dans le sud-ouest de l'Algérie, sont activement menées dans ce travail.

L'enquête ethnobotanique a été menée dans le but de recueillir des informations détaillées sur l'utilisation des plantes en thérapie humaine dans la région de Bechar. Au total, 162 espèces de plantes représentant 143 genres et 50 familles ont été utilisées dans le traitement de diverses maladies. Les familles de plantes médicinales les plus rencontrées étaient Asteraceae (18 spp.), Apiaceae et Lamiaceae (12 spp. Chacun). Les feuilles des plantes étaient la partie la plus couramment utilisée. Tandis que la décoction et le cataplasme étaient les méthodes les plus courantes de préparation de médicaments traditionnels.

L'évaluation du contenu phytochimique, la puissance antioxydante et l'activité antibactérienne des extraits aqueux et hydrométhanoliques de neuf plantes médicinales folkloriques de la région de Bechar, à savoir : *A. nardus, A. schoenanthus*, *G. alypum*, deux espèces de *H. scoparia* vert & rouge, *P. laevigata, R. tripartita, T. gallica* et *T. nudatum*.

Parmi tous les extraits, l'extrait aqueux de *R. tripartita* (276.221±0.079 mg GAE/g) et les extraits hydrométhanoliques de *P. laevigata* et *H. scoparia* rouge (245.095±0.037 et 243.609±0.231 mg GAE/g respectivement) ont montré le plus haut Contenu phénolique. Les extraits hydrométhanoliques de *P. laevigata, R. tripartita* et *G. alypum* ont montré la teneur la plus élevée en flavonoïdes (646.531±0.234, 510.531±0.023 et 494.197±0.077 mg QE/g respectivement), alors que les extraits hydrométhanoliques d'*A. schoenanthus*, *R. tripartita* et *H. scoparia* vert ont montré la teneur la plus élevée en polysaccharides (356,609±0,005, 350,440±0,049 et 344,957±0,046 mg GE/g respectivement).

L'activité antioxydante réalisée par DPPH, FRAP et TAC montre que les deux extraits de *R. tripartita* présentaient une activité antioxydante totale plus élevée avec une IC_{50} très faible (15,838 et 19,539 mg / ml respectivement). Les extraits hydrométhanoliques de *R. tripartita*, *P. laevigata*, *T. gallica* et *H. scoparia* rouge ont la plus forte puissance antioxydante réductrice de ferrique (624.194±0.294, 589.195±0.054, 470.423±0.141 et 436.914±0.153 AAEFRAP/g respectivement). Alors que les extraits aqueux et hydrométhanolique de *R. tripartita* (426,581±0,1812 et 361,507±0,326 mg AAE/g respectivement) et les extraits hydrométhanoliques de *T. gallica*, *H. scoparia* rouge et *P. laevigata* (295.166±0.165, 289.673±0.051 et 264.108±0.170 mg AAE/g respectivement) possédaient la capacité antioxydante totale la plus élevée.

L'activité antibactérienne maximale a été enregistrée contre les souches de référence gram-négatives *Pseudomonas aeruginosa* et *Escherichia coli* avec un diamètre d'inhibition maximal de 15.6±0.5 et 15.0±1.4 mm, respectivement, enregistré par l'extrait aqueux de *T. gallica*.

L'activité antifongique a révélé que l'extrait hydrométhanolique de *R. tripartita* et l'extrait aqueux de *T. nudatum* étaient les meilleurs pour inhiber la croissance *d'Aspergillus nidulans* (77 et 66% respectivement).

Mots clés :

Plantes médicinales, enquête ethnobotanique, screening phytochimiques, activité antioxydante, activité antibactérienne, activité antifongique, région de Bechar, sud-ouest de l'Algérie.

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List of Abbreviation

AAE	Ascorbic Acid Equivalent
AD	Anno Domini
ANOVA	Analysis Of Variance
ATCC	American Type Culture Collection
BC	Before Christ
CE	Common Era
COVID	Coronavirus Disease
DMSO	Dimethylsulfoxide
DPPH	2,2-Diphenyl-1-Picrylhydrazil
FRAP	Ferric Reducing Antioxidant Power
GAE	Gallic Acid Equivalent
GE	Glucose Equivalent
HIV	Human Immunodeficiency Virus
HPLC	High-Performance Liquid Chromatography
IC_{50}	Half-Maximal Inhibitory Concentration
QE	Quercetin Equivalent
SARS-CoV	Severe Acute Respiratory Syndrome Coronavirus
SD	Standard Deviation
TAC	Total Antioxidant Capacity
TFC	Total Phenolic Content
TLC	Thin Layer Chromatography
TPC	Total Flavonoids Content
TPSC	Total Polysaccharides Content
UV	Ultraviolet Spectroscopy
WHO	World Health Organization

General Introduction

Gift of nature is medicinal plants to provide disease-free healthy life as they play an important role in protective health (Das et al., 2019; Saber et al., 2020). World's cultures have broad information of natural medicine, today. Traditional medicine depends on convictions and practices which existed before the improvement of "modern medicine" or "scientific drug therapy" (Sagadevan et al., 2019).

Therefore, a question arises as to why we should not use all the tools of modern science to consider these medicines again. Further research may lead to the discovery of new modes of action, new biologically active compounds, confirmation of traditional uses, or in the worst case, no activity is present, and even that a given medicine's use can carry risks of toxicity (Gautam et al., 2011; Pawar et al., 2018; Verpoorte, 2009; Williamson et al., 2009).

Africa is the world's second-largest continent after Asia, both in terms of area and population. The continent has a unique diversity of geographic and climatic factors and its flora is exceptionally rich and varied with an estimated 68,000 plant species, of which about 35,000 are known to be endemic (Kumar, 2004; PROTA, 2013; Saive et al., 2018).

The region of North Africa, having arid, semi-arid, and a range of sub-climatic zones, consists of the biota of the semi-closed Mediterranean and Red seas, with diverse ecosystems constituting about 10,000 vascular plant species (Suttie et al., 2005). About 70% of plant species found in the wild have medicinal, aromatic, and other uses. Over 10% of these have the potential for commercial exploitation as a source of drugs and pharmaceuticals (Kumar, 2004).

A massive country with a wide variety of landscapes and ecological zones, Algeria has a rich natural heritage (Kambouche et al., 2010). Considered by many to be the most unique natural country of the Mediterranean, Algeria's distinctive morphology, varied topography and under changing climatic conditions permits the growth of more than 3000 plant species (Benamar et al., 2010; Fatehi et al., 2017).

A lot of ethnobotanical research documented a large number of medicinal plants in Algeria, most have remained undocumented and uncharacterized, the knowledge of their use being passed down from generation to generation by word of mouth. The use of plants in the local traditional medicine is sustained by their biological activities either scientifically proven or not.

In regions like southwestern Algeria, where the primary health care system of a majority of the population is traditional medicine, studies are necessary to assess the activity, the toxicity, and the interaction of the plants with conventional medicine. Those plants have already been used by generations of the native population, which may assess their efficacy and safety.

Thesis Overview

An Ethnobotanical Survey as well as the search for bioactive chemical substances produced by folkloric medicinal plants, from the Bechar region (Southwest Algeria), is the main focus of this research.

This research has been divided into three major chapters:

The first chapter briefly introduces the historical context of medicinal plants and presents information on the natural products (main classes and drug discovery from plants, antioxidant and antimicrobial activities of plant derivatives). It also gives a general idea about the traditional medicinal plants chosen to be investigated in this context.

The second chapter describes methods used in the experimental work which includes the ethnobotanical survey, extraction procedure, qualitative and quantitative phytochemical, antioxidant and antimicrobial screening of nine-folkloric medicinal plants. Whereas, the third chapter discusses the results found in detail.

Finishing with a general conclusion that contains a global overview of all the studies conducted in this thesis.

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Chapter 1

Literature Review

I. INTRODUCTION

Medicinal plants have been prescribed and used extensively for thousands of years to treat various disorders and ailments in traditional herbal medicine systems all over the world (Chaachouay et al., 2022).

Currently, More than 80% of the world's population are facing difficulties to afford synthetic drugs and are relying on traditional medicines mainly of plant origin to maintain their health care (Vinodhini and Rajeswari, 2018; Zikri et al., 2018), which makes sense to devote much more resources to such researches (Kumar et al., 2018; Monisha et al., 2018). Many more hidden gems may be found through studies of medicinal plants (Abubacker et al., 2018).

II. MEDICINAL PLANTS

Throughout the ages, humans have relied on nature to cover all their basic needs for the production of food, shelter, clothing, transportation, fertilizers, flavors and fragrances, and medicines (Aslam et al., 2016; Beyene, 2016; Jain et al., 2019). According to the Worlds Health Organization, any plant which contains a substance that can be used for therapeutic purposes or which are precursors of chemo pharmaceutical semi-synthetic new drug is referred to as medicinal plants (Jain et al., 2019).

Out of the 250,000 to 500,000 species of existing plants on earth (Hong et al., 2018; Vinodhini and Rajeswari, 2018), more than 80,000 species are reported to have at least some medicinal value and around 5,000 species have specific therapeutic value, which means that almost 25% of all plant species have some sort of medicinal use somewhere in the world (Chafamo et al., 2018; Chothani and Patel, 2018; Thakur and Sharma, 2015).

II.1. Traditional Medicine

Traditional medicine, as defined by the World Health Organization, is "the total sum of the knowledge, skills, and practices which are based on the theories, beliefs, and experiences indigenous to different cultures, whether explicable or not, used in the maintenance of health, as well as in the prevention, diagnosis, improvement or treatment of physical and mental illnesses" (Kiessoun *et al.*, 2019; Gakuya *et al.*, 2020; Salmerón-

Manzano, Garrido-Cardenas, and Manzano-Agugliaro, 2020; Chung *et al.*, 2021).

In general considerations, practices of traditional medicine vary greatly from country to country, and from region to region, as they are influenced by factors such as culture, history, personal attitudes, and philosophy (Che *et al.*, 2017; Parandhaman, Thiruthani, and Balamani, 2018).

Long historical use of many practices of traditional medicine, including experience passed on from generation to generation, has demonstrated the safety and efficacy of traditional medicine. However, scientific research is needed to provide additional evidence of its safety and efficacy (Iqbal *et al.*, 2018; Grujičić, Marinković and Milošević-Djordjević, 2020; Salmerón-Manzano, Garrido-Cardenas, and Manzano-Agugliaro, 2020).

II.1.1 Traditional Medicine Throughout the Ages

Medicinal plants, since times immemorial, have been used in virtually all cultures as a source of medicine (Alhassan et al., 2020; Kavitha and Krithika, 2018). The widespread use of herbal remedies and healthcare preparations, like those described in ancient texts such as the Holy Quran and the Prophetic Sunnah (Islamic civilization), the Bible (European civilization), and Vedas (Indian civilization), has been traced to the occurrence of natural products with medicinal properties (Alhassan et al., 2020; Angamuthu et al., 2016; Jain et al., 2019; Nishad et al., 2018).

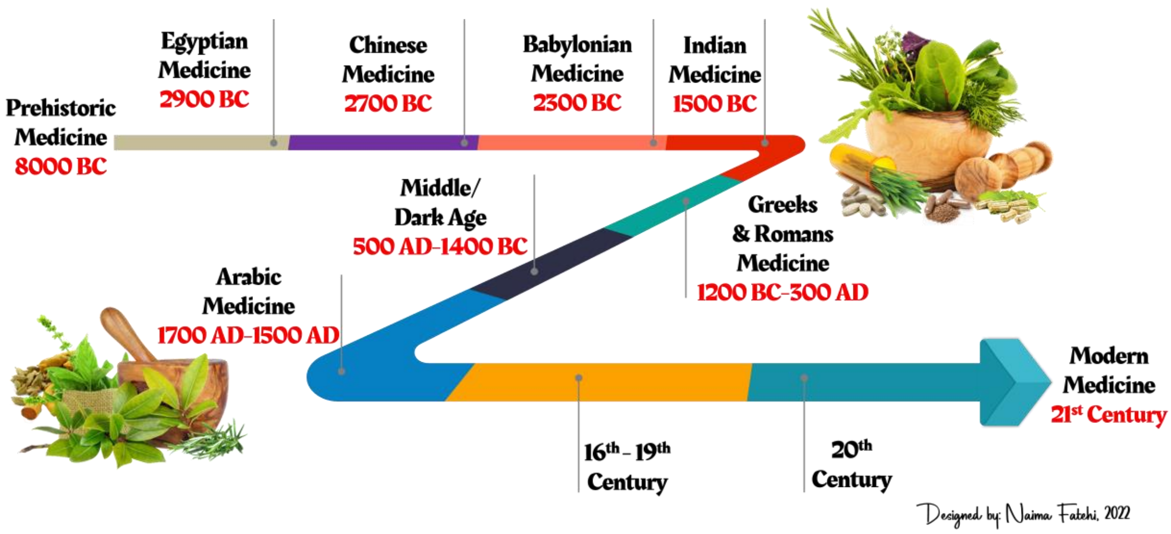


Figure I.1. Timeline of Medical History

II.1.1.1. Prehistoric Medicine

Since prehistoric times, humans have used plants, animals, microorganisms, and marine organisms, in medicines to alleviate and treat diseases (Salmerón-Manzano, Garrido-Cardenas, and Manzano-Agugliaro, 2020). According to fossil records, the human use of plants as medicines may be traced back at least 60,000 years (Fierascu et al., 2017; Yuan et al., 2016). Through trial and error, they found plants that were agreeable or distasteful, edible or poisonous, that could cure or kill, could induce sleep, visions, or euphoria, and relieve symptoms of discomfort from constipation or anxiety (Salmerón-Manzano et al., 2020).

II.1.1.2. Traditional Nile Valley Medicine

Civilization in Egypt was not only the pyramids and tombs, but it involved all aspects of human life including health and medicine (Elhabashy and Abdelgawad, 2019). The Ancient Egyptians were quite advanced in their diagnoses and treatments of various illnesses. Their advancements in ancient medical techniques were quite extraordinary, considering the lack of “modern” facilities, sterilization, sanitation, and researching capabilities (Aboelsoud, 2010). Along with their strong faith in their gods, the Ancient Egyptians used their knowledge of the human anatomy and the natural world around them to treat ailments and disorders effectively (Elhabashy and Abdelgawad, 2019).

The remedies used by ancient Egyptian physicians came mostly from nature, especially medicinal herbs. The Egyptian medicine dates from about 2900 BC but their best known pharmaceutical record is *Ebers Papyrus* written in about 1500 BC which includes over 700 drugs (involving the use of plant extracts, animal organs, and minerals) and formulae such as gargles, snuffs, poultices infusions, pills and ointments (Dafni and Böck, 2019; Elhabashy and Abdelgawad, 2019; Ventegodt, 2020; Wilson, 1962).

II.1.1.3. Traditional Assyrian and Babylonian Medicine

The Assyrians, who ruled in Mesopotamia in the first half of the first millennium BC, greatly consolidated ancient knowledge about herbal remedies. They left a legacy of 1500 years of herbal medicine (1900 to 400 BC) that extolled the virtues of around 1,000 medicinal plants and remedies including enemas and poultices for exorcism of spirits

(Dafni and Böck, 2019). The written traditions of Babylonian and Assyrian medicine are largely, of Babylonian origin, though it appears that there was a new emphasis in Assyria, particularly under the king Assurbanipal (reigned 668-627 BC). In recent years, it has become increasingly clear that the written medical traditions continued in Babylonia after the fall of Assyria (Biggs, 2005; Dafni and Böck, 2019).

II.1.1.4. Traditional Chinese Medicine

Traditional Chinese medicine has a long history of serving people, which tends to raise the natural defenses of the organism instead of trying to restore its natural functions. The Chinese *Materia Medica* has been extensively documented over the centuries with the first record dating from about 1100 BC (Schnell, 2018).

However, the first herbalist that concentrated on cataloging and describing therapeutically effective substances appears to have been compiled in China by Shennong Bencao Jing (100-200 AD) and covered 365 herbal drugs at the same time as the *Materia Medica of Dioscorides* (Yoshikawa and Matsuda, 2006a). In Chinese herbal medicine, formulas are chosen based on patterns of illness or imbalance, not just symptoms (Huang, 2018). This pharmacopeia contains almost 6000 herbs usually formulated in mixtures of up to 20 herbs (Tzimas et al., 2020).

II.1.1.5. Traditional Indian Medicine

Ayurvedic medicine (also called Ayurveda) is an ancient tradition from India and because it literally means "knowledge of life" encompasses more than just medicinal aspects, as it includes psychological, cultural, religious, and philosophical concepts (Jain et al., 2019; Jyoti et al., 2018). This system classifies individuals according to three determined body types or *doshas* where the medicinal approach is to restore the balance of the whole body rather than suppress symptoms. Documentation of the Indian Ayurvedic system dates from about 1000 BC and provided the basis for the primary text of Tibetan medicine (Jain et al., 2019; Jyoti et al., 2018).

II.1.1.6. Traditional Greek Medicine

Greek civilization is the source of philosophy that literally means friend of wisdom. Greek philosophy involved a search for rational explanations of events in the natural world, including the healing arts. In the ancient Western world, the Greeks contributed significantly to the rational development of the use of herbal drugs with *Hippocrates* (460-377 BC), *Aristotle* (384-322 BC), and *Theophrastus* (circa 300 BC) to have dealt with the medicinal properties of herbs (Chanda et al., 2019; Kumar and Rajpoot, 2018; Tzimas et al., 2020).

After the decline of the Greek empire with the death of Alexander the Great (323 BC), several contributions were accomplished, and it is worth mentioning the eight volumes of *De Medicina* by *Celsus* that includes over 250 plant-derived remedies. Probably the most significant contribution was made by *Dioscorides*, a Greek physician (100 AD), during his travels with Roman armies. He recorded the collection, storage, and use of medicinal herbs. His legacy was a five-volume work entitled *De Materia Medica* written in the first century AD; it described 600 plants and plant products. Although poorly organized, it became the model for future pharmacopeias (Lain-Entralgo, 1992; Ventegodt, 2020).

II.1.1.7. Traditional American Medicine

Regarding the American continent, the oldest known medical text is the *Badianus* manuscript composed by Aztec scholars. It depicts many of the most important plants employed in Aztec medicine and it is the earliest pharmacopeia from the Americans. The number of species employed by Native Americans is staggering since, from 17 000 plant species that constitute the North American flora, only 2800 continue to be used for medicinal purposes by various Native American people. Conquest and colonization of America by Europeans were accompanied by an unprecedented blending of old and new world diseases, ethnomedical systems, and plant-based pharmacopeias (Borchers et al., 2000; Schnell, 2018; Voeks, 1993).

II.1.1.8. Traditional African Medicine

Africa is considered to be the cradle of Mankind with a rich biological and cultural diversity marked regional differences in healing practices (Egwaikhide, Okeniyi, and Gimba, 2007). Therefore, African traditional medicine is the oldest and perhaps the most diverse of all medicine systems. It is a holistic discipline that utilizes indigenous herbalism combined with some aspects of African spirituality, and a fundamentally different form of healing from biomedicine. This idea is embedded in the African belief that serious life-threatening illness may be underpinned by the anger of supernatural agencies such as *Asancestor* spirits acting to enforce community moral laws (Ajima and Ubana, 2018).

Unfortunately, the systems of medicines are poorly recorded and remain so to date. Yet the documentation of medicinal uses of African plants is becoming increasingly urgent because of the rapid loss of the natural habitats of some of these plants because of anthropogenic activities (Oladipo and Adeniji, 2020; Willcox and Bodeker, 2010).

II.1.1.9. Traditional Arab-Islamic Medicine

A century after the death of the prophet Muhammad (PBUH), his followers had conquered half of Byzantine Asia, all of Persia, Egypt, North Africa, and Spain. It was during the Islamic empire era that the first great scientific advances in medicine were made (Alrawi and Fetters, 2012; AlRawi and Fetters, 2019).

The history of Islamic medicine can be conveniently divided into three phases, characterized briefly as follows (Alrawi and Fetters, 2012):

A. Phase of translation of foreign scientific sources into Arabic (7^{th}-9^{th} centuries): The most famous of all the translators was ***Hunain ibn Isha´q*** who translated, with his team, a large number of medical works of *Hippocrates* and *Galen*, as well as philosophical works by *Plato* and *Aristotle*. By the tenth century AD, all essential Greek medical writings were being translated into Arabic, and Arabic became the international language of learning and diplomacy (Syed, 2002).

B. Phase of excellence and genuine contribution (9th-13th centuries)

Since Christians lost their monopoly of medicine, a great civilization was established through which the torch of knowledge spread to Europe. The era of Islamic Medicine introduced some very famous and notable physicians (Hosseini et al., 2018) such as:

Muhammed ibn-Zakariya al-Razi or *Rhazes* who wrote *the Inclusive Work on Medicine* and *The Mansurian Book of Medicine* that represents a major contribution to the pharmacy. Rhazes demonstrated the toxicity of many of the popular remedies based on heavy metal salts, particularly those involving mercury.

Abu Ali al-Hussain ibn Sina or *Avicenna* was the greatest philosopher and scientist in Arab history. He wrote two hundred and fifty works. Nevertheless, his vast *Canon of Medicine* is rightly acclaimed as the *culmination and masterpiece of Arab systematization*. He also wrote *Kitab al-Shifa*, or *The Book of Healing*, which rivals in extent the Aristotelian corpus. The work contained the knowledge needed for curing the soul as well as physical illness and included some important chapters dealing with logic, mathematical and natural sciences(Alrawi and Fetters, 2019).

Ibn al-Baitar who wrote the comprehensive compilation known as *Corpus of Simples* by This treatise listed over 1400 drugs including 800 plant-derived drugs, 145 from minerals, and 130 from animals (Oumeish, 1999; Saad et al., 2005).

C. Phase of decline (after 13th century): The phase of Arab-Islamic medicine started when European scholars interested in science and philosophy came to appreciate how much they had to learn from the Arabs, and set about studying Arab works in these disciplines and translating the chief of them into Latin and became a basis for the development of modern medicine. Muslims have fostered the flame of civilization and handed it over to Europe in the best possible condition. Europe, in turn, passed it to the United States of America (Alrawi and Fetters, 2012; Thoker and Patel, 2020).

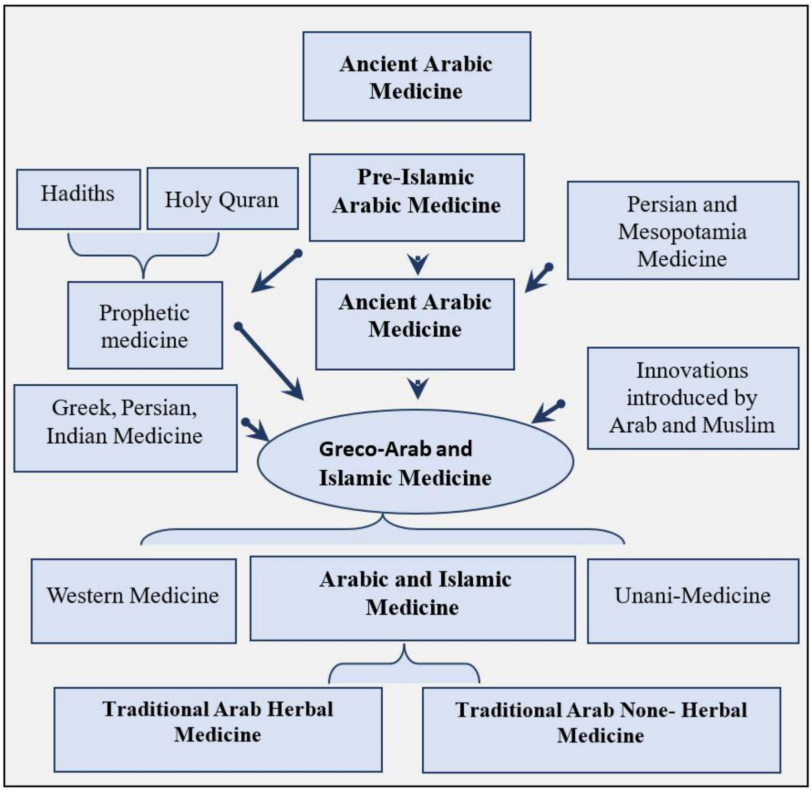


Figure I.2. Traditional Arab-Islamic Medicine Development

II.2. Modern Pharmacology

Until the 18th century, the therapeutic properties of many plants, their effect on the human organism, and their method of treatment were known, but the active compound was unknown (Salmerón-Manzano, Garrido-Cardenas, and, Manzano-Agugliaro, 2020).

The origin of modern science, especially in the Renaissance, in particular chemical analysis, and the associated instrumentation such as the microscope, was what made it possible to isolate the active principles of medical plants (Salmerón-Manzano, Garrido-Cardenas, and Manzano-Agugliaro, 2020).

In the *Skeptical Chymist* published in 1661, Robert Boyle laid the foundations for an understanding of the chemistry of drugs (Bishop and Gill, 2020). The discovery of the effectiveness of *Digitalis* by William Withering (1741-1799) for the treatment of dropsy is considered by many as the beginning of modern pharmacology (Curfman, 2020).

In the early 1800's the isolation of the active principles of commonly used plants and herbs such as strychnine (1817), morphine (1816), atropine (1819), quinine (1820) and colchicine (1820) were achieved (Dias, Urban, and Roessner, 2012). The first semi-synthetic pure drug based on a natural product, acetylsalicylic acid (aspirin), by Bayer in 1899 then followed these isolations. In the first half of the twentieth century, many substances with current medicinal use were obtained from traditional plant-derived extracts (Bhat, Nagasampagi, and Sivakumar, 2005).

Many ancient traditional medicine systems are practiced all over the world despite advances in modern medicine mainly because of its historical circumstances and cultural beliefs, especially the Chinese Traditional Medicine and the Ayurvedic system which are alive despite the efforts of the pharmaceutical companies to dismiss them claiming health concerns (Nishad et al., 2018).

Traditional knowledge along with its associated pharmacopeias has played a major role in drug discovery and it is a matter of political debate between native people and pharmaceutical companies (Vijayvergia and Khatana, 2019; Salmerón-Manzano, Garrido-Cardenas, and Manzano-Agugliaro, 2020).

II.3. Ethnopharmacology

The selection of a suitable plant for the pharmacological study is a very important and decisive step (Saive, Frederich, and Fauconnier, 2018). There are several ways in which this can be done, including traditional use, chemical content, toxicity, and randomized selection; it is also possible and often desirable and sometimes inevitable to use a combination of several criteria (Nishad et al., 2018). The most common strategy is the careful observation of the use of natural resources in folk medicine from different cultures; this is known as ethnobotany or ethnopharmacology (Díaz, 1977; Wairt, 2006).

From its original definition, as a multidisciplinary area of research, concerned with the observation, description, and experimental investigation of indigenous drugs and their biological activities, the term ethnopharmacology has undergone only slight evolution in meaning; its contemporary definition addresses the interdisciplinary study of the physiological actions of plants, animals and other substances used in indigenous medicines of past and present culture (Cahlíková et al., 2020; Nishad et al., 2018).

II.4. Drug Discovery from Medicinal Plants

II.4.1. Pharmacognosy

Drug discovery from plants involves a multidisciplinary approach combining ethnobotanical, phytochemical, and biological techniques to provide us with new chemical compounds for the development of drugs against various pharmacological targets (Cahlíková et al., 2020; Sarker, 2012).

The process typically begins with a botanist, ethnobotanist, ethnopharmacologist, or plant ecologist who collects and identifies the plant(s) of interest. Collection may involve species with known biological activity for which active compound(s) have not been isolated or may involve taxa collected randomly for a large screening program (Nishad, Anu, and Sundar, 2018). Phytochemists prepare extracts from the plant material, subject these extracts to biological screening in pharmacologically relevant assays, and commence the process of isolation and characterization of the active compound(s) through bioassay-guided fractionation. Molecular biology has become essential to medicinal plant drug discovery through the determination and implementation of appropriate screening assays directed towards physiologically relevant molecular targets (Jain et al., 2019; Sarker, 2012). Pharmacognosy encapsulates all of these fields into a distinct interdisciplinary science (Cahlíková et al., 2020; Hacker, 2009).

II.4.2. Drug Discovery from Medicinal Plants: Methods

Numerous methods used to acquire compounds for drug discovery include isolation from plants and other natural sources; synthetic chemistry; combinatorial chemistry, and molecular modeling. Despite the recent interest in molecular modeling, combinatorial chemistry, and other synthetic chemistry techniques by pharmaceutical companies and funding organizations, natural products, and particularly that of medicinal plants, remains an important source of new drugs, drug leads, and chemical entities (Dif et al., 2014; Ertl and Schuffenhauer, 2008; Nishad et al., 2018).

II.4.3. Drug Discovery from Medicinal Plants: Challenges and Charges

Despite evident successes of drug discovery from medicinal plants, future endeavors face many challenges (Cole, Farooq, and Murch, 2009). Pharmacognosists, phytochemists, and other natural product scientists will need to continuously improve the quality and quantity of compounds that enter the drug development phase to keep pace with other drug discovery efforts (Liu and Wang, 2008).

Recently problems with serious side effects caused that several novel medicines had to be taken off the market shortly after their introduction. This does not also help to increase efforts at novel drug development. The process of drug discovery has been estimated to take an average of 10 years upwards and cost more than 800 million US dollars. Much of this time and money is spent on the numerous leads that are discarded during the drug discovery process. It has been estimated that only one in 5,000 lead compounds will successfully advance through clinical trials and be approved for use. Lead identification is only the first step in a lengthy drug development process (Yu and Lee, 2006; Cardoso, de Oliveira, and Cardoso, 2019).

Drug discovery from medicinal plants has traditionally been lengthier and more complicated than other drug discovery methods, therefore, many pharmaceuticals have eliminated or scaled down their natural product research (Kingston et al., 2000).

II.4.4. Drug Discovery from Medicinal Plants: The Future

As mentioned earlier, the number of higher plant species (angiosperms and gymnosperms) on this planet exceeds 500,000 (Hong, Lee, and Kim, 2018; Vinodhini and D. Rajeswari, 2018). Of these, only about 6% have been screened for biologic activity, and a reported 15% have been evaluated phytochemically (Fabricant and Farnsworth, 2001). With high throughput screening methods becoming more advanced and available, these numbers will change (Cordell, 2002; Marcaurelle and Johannes, 2008).

Moreover, medicinal plant research includes much more than the discovery of new drugs. Recently, this field has been expanding to also include such diverse subjects as negotiation of power based on medicinal plant knowledge and the co-evolution of humans and plants. The field also provides opportunities to study how human interaction with biological diversity is influenced by human psychology, cognition, and evolution. Therefore, the identification of active plant chemicals is an essential component of modern pharmacognosy and medical effects are not necessarily restricted to a single plant chemical. The biological activity and clinical value of the whole plant, as in medicinal herbalism, is also being pursued (Cahlíková et al., 2020; Nishad et al., 2018).

III. Natural Products

Natural Products can be thought of as originating from mankind's curiosity about odor, taste, and cures for diseases (Chulet et al., 2010; Daniela et al., 2007; Firn, 2010). Whether it is their fascinating biological function or remarkable structural architecture, compounds isolated from natural sources have played an integral role in the inspiration and advancement of scientific knowledge across a wide range of disciplines (Abegaz and Kinfe, 2019; Maddess et al., 2008; Teklit and Birhanu, 2018).

As mentioned earlier, approximately 80% of the world's inhabitants rely mainly on traditional medicines for their primary healthcare. For the remaining 20% of the world's population, mainly residing in developed countries, nature is equally important since approximately 25% of the prescribed drugs contain extracts or plant metabolites and an additional significant percentage of the market drugs have been developed through studies employing natural products as the lead molecules (Ioannou and Roussis, 2009; Majouli et al., 2018). More than 60% of the anticancer and 70% of the anti-infective antibiotics currently in clinical use are natural products or natural products-based compounds (Abdel lateif, Maghrabi, and Eldeab, 2016; Sagadevan *et al.*, 2019).

III.1. Bioactive Molecules of Medicinal Plants

Many different kinds and types of organic compounds or metabolites are produced in plants as a result of metabolic processes. These metabolites are grouped into primary and secondary metabolites (Amabye, 2015; Sagadevan et al., 2019).

The primary metabolites like chlorophyll, amino acids, nucleotides, simple carbohydrates, or membrane lipids, play recognized roles in photosynthesis, respiration, solute transport, translocation, nutrient assimilation, and differentiation (Haas and Hill, 1926). The carbon skeleton of all the compounds is derived from carbohydrates synthesized by photosynthesis. These kinds of products are rarely relevant as pharmacologically active substances. Nonetheless, they may have a positive or negative effect on the efficacy of the active principles in drugs (Cseke and Kaufman, 1998).

The secondary metabolites differ from primary metabolites in having a restricted distribution in the plant kingdom. That is, particular secondary metabolites, known as phytochemicals, are often found in only one plant species or a taxonomically related group of species, whereas the basic primary metabolites are found throughout the plant kingdom. These organic chemical substances are stored in matured cells of the various organs, such as roots, stems, leaves, flowers, fruits, and seeds (Abegaz and Kinfe, 2019; Duru and Onyedineke, 2010; Jain et al., 2019; Nasir et al., 2015).

III.2. Plant Secondary Metabolites

The potential use of plant secondary metabolites in health care and personal care products, and as lead compounds for the development of novel drugs, leads to a huge interest in their isolation and characterization from major plant species. At present, the total number of identified secondary metabolites exceeds 500,000 (Singer, Crowley, and Thompson, 2003; Zhang *et al.*, 2004). These can be grouped into three main chemical classes: Phenolic, Nitrogen-containing compounds, and terpenoids (Amabye, 2015; Briskin, 2001; Kennedy and Wightman, 2011; Mazid et al., 2011; Wink, 1999).

Table I.1. Number of Known Secondary Metabolites from Higher Plants (Wink, 2010)

Type of secondary metabolite	Number
Nitrogen-containing	
Alkaloids	21 000
Non-protein amino acids	700
Amines	100
Cyanogenic glycosides	60
Glucosinolates	100
Alkamides	150
Lectins, peptides, polypeptides	2000
Without nitrogen	
Monoterpenes (C10)	2500
Sesquiterpenes C15)	5000
Diterpenes (C20)	2500
Triterpenes, steroids, saponins (C30, C27)	5000
Tetraterpenes (C40)	500
Flavonoids, tannins	5000
Phenylpropanoids, lignin, coumarins, lignans	2000
Polyacetylenes, fatty acids, waxes	1500
Polyketides	750
Carbohydrates, organic acids	200

III.2.1. Plant Secondary Metabolites Role

During the past few decades, experimental and circumstantial evidence has made it clear that many secondary metabolites do indeed have functions that are vital for the fitness of a plant producing them (Isah, 2019; Jain et al., 2019; Labarrere et al., 2019; Velu et al., 2018; Wink, 2010; Wink and Schimmer, 2010; Yang et al., 2018).

Functions of plant secondary metabolites comprise:

- Defense against herbivores (insects, vertebrates),
- Defense against fungi and bacteria, defense against viruses,
- Defense against other plants competing for light, water, and nutrients,
- Signal compounds to attract pollinating and seed-dispersing animals,
- Signals for communication between plants and symbiotic microorganisms,
- Protection against UV light or other physical stress.

Besides, they have also provided an invaluable resource that has been used to find new drug molecules (Abegaz and Kinfe, 2019; Madiha et al., 2018; Oluwakemi et al., 2018; Sharma et al., 2011; Wink and Schimmer, 2010).

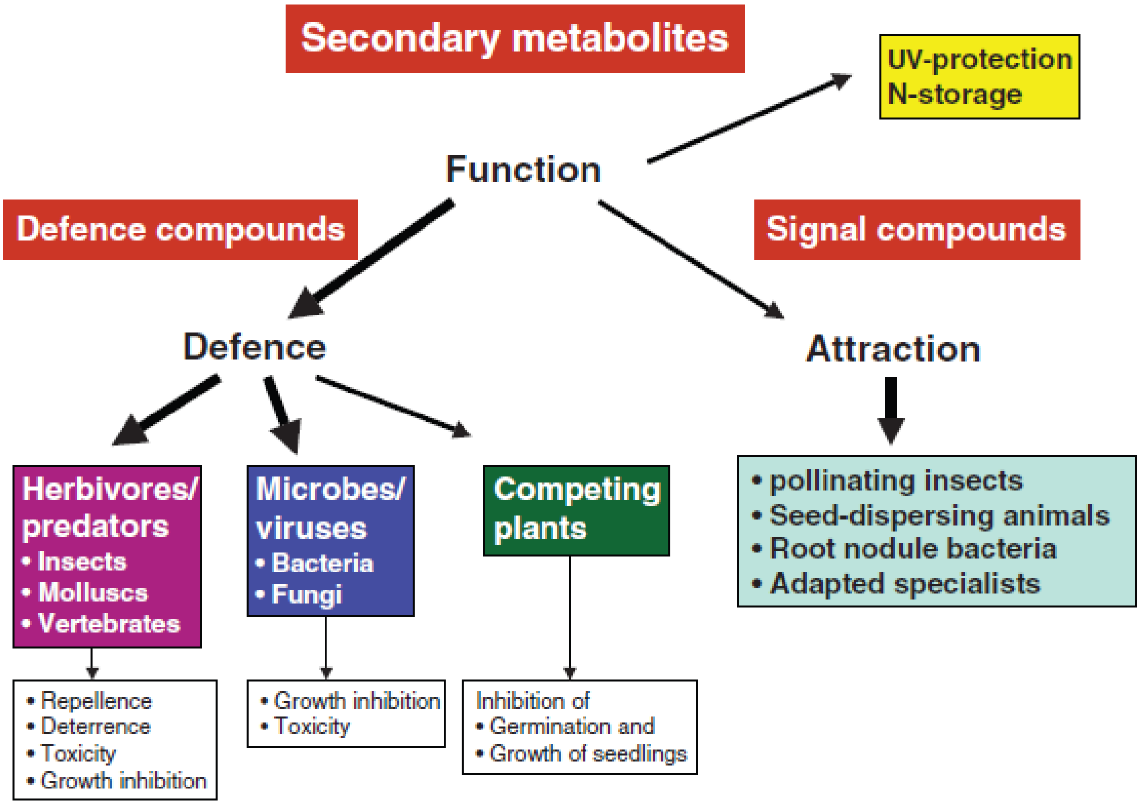


Figure I.3. Most Common Functions of Plant Secondary Metabolites

III.2.2. Plant Secondary Metabolites Synthesis

The majority of secondary metabolites are synthesized via two principal biosynthetic pathways:

(1) Shikimic Acid pathway producing a pool of aromatic amino acids, which in turn are converted into diverse compounds such as phenolics (lignins, tannins, quinones) and alkaloids, and

(2) Acetyl-CoA Mevalonic Acid pathway leading to a vast array of terpenoids (Abegaz and Kinfe, 2019; Carrington et al., 2018; Isah et al., 2018; Pott et al., 2019; Wink, 2010). The synthesis of various classes of secondary metabolites is presented in schematic form in (Figure I.4).

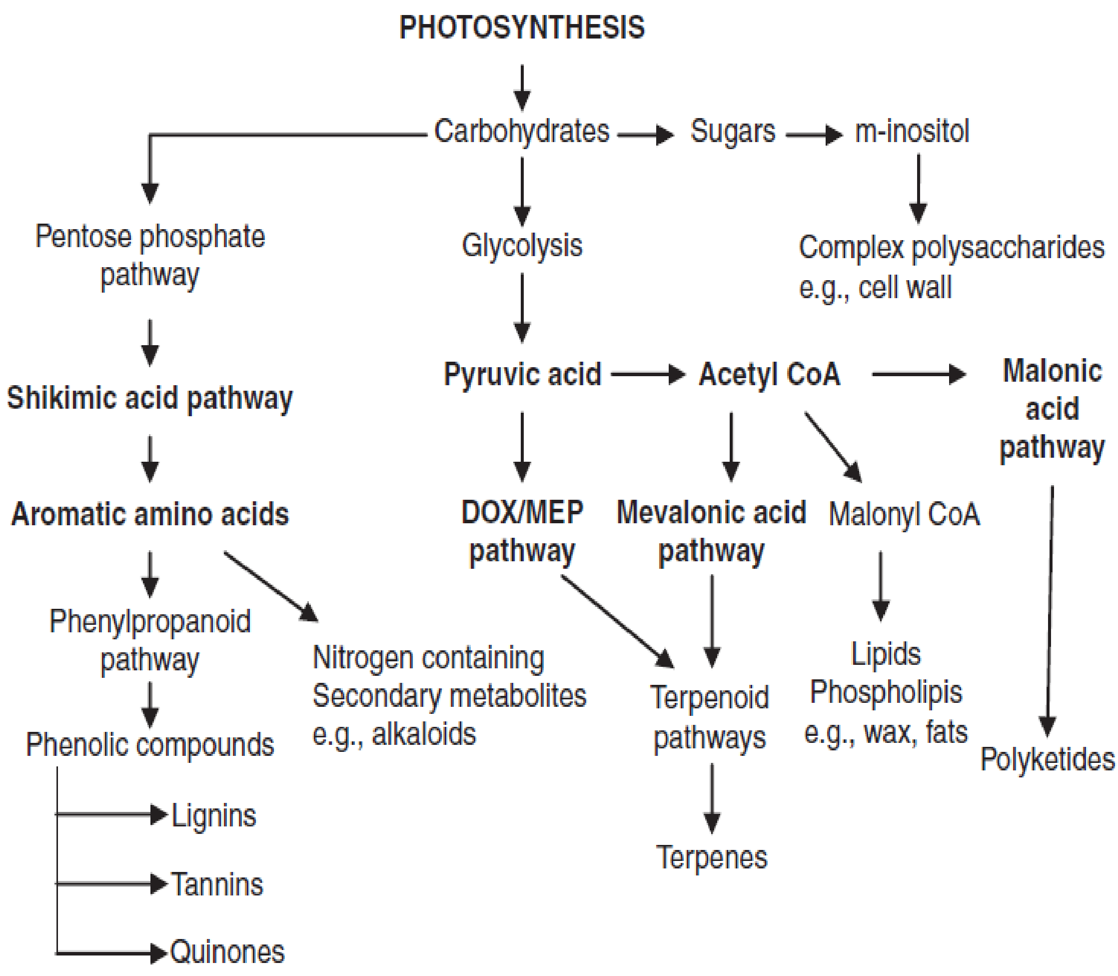


Figure I.4. Principal Biosynthetic Pathways

III.2.3. Plant Secondary Metabolites Classes

As mentioned earlier, the total number of identified secondary metabolites exceeds 500,000. These natural products can be classified based on composition, the pathway by which they are synthesized, or chemical structure (Harborne and Baxter, 1993; Abegaz and Kinfe, 2019; Jain, Vijayvergia and Khatana, 2019).

III.2.3.1. Alkaloids

The alkaloids are organic nitrogenous bases found mainly in plants, but also to a lesser extent in microorganisms and animals. With currently, more than 21,000 known structures, alkaloids represent one of the biggest groups of natural products (Guerra and Issinger, 2019).

In most alkaloids, the nitrogen atom is a part of the ring, they are biosynthetically derived from amino acids (Kohnen-Johannsen and Kayser, 2019; Roberts et al., 2010).

They are generally classified according to the amino acid that provides both the nitrogen atom and the fundamental alkaloidal skeleton. However, alkaloids can also be grouped based on their generic structural similarities (Bribi, 2018; Salminen et al., 2011).

Several natural alkaloids and their derivatives have been developed as drugs to treat various diseases (Bribi, 2018; Guerra and Issinger, 2019; Wink, 2008). For example, the well-known plant alkaloids include the narcotic analgesics, morphine, and codeine, apomorphine (a derivative of morphine) used in Parkinson's disease, the muscle relaxant papaverine, and the antimicrobial agents sanguinarine and berberine. Also, several potent anti-cancer drugs have been developed from plant compounds (Bribi, 2018; Guerra and Issinger, 2019; Jain, Vijayvergia, and Khatana, 2019).

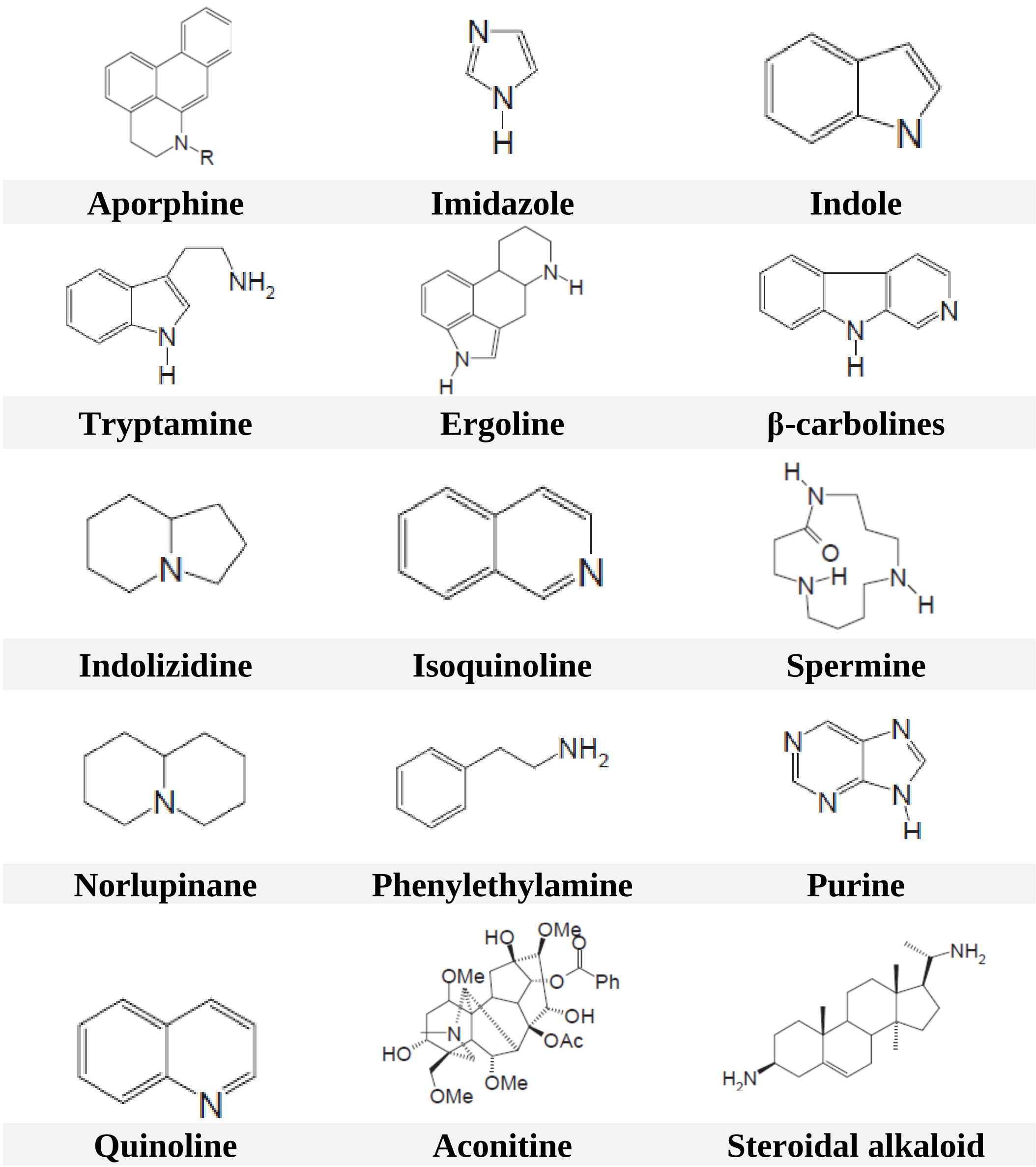


Figure I.5. Chemical Structures of Some Known Alkaloids

III.2.3.2. Terpenoids

The terpenoids, also named isoprenoids, are among the most structurally, stereochemically, and biologically diverse family of natural products. Greater than 55,000 unique terpenoid entities have been discovered in living organisms (Hsieh *et al.*, 2011; Santos *et al.*, 2011; Himmelberger, Cole, and Dowling, 2018). Despite their structural diversity, they have a simple unifying feature by which they are defined and by which they may be easily classified. They are compounds derived from a combination of two or more isoprenoids units (Chen et al., 2018).

Many isoprenoids are present in all plants and act as primary metabolites with roles in respiration, photosynthesis, and regulation of growth and development. However, the highest variety of isoprenoids is secondary metabolites that function in protecting plants against herbivores and pathogens, in attracting pollinators and seed-dispersing animals, and as allelochemicals that influence competition among plant species (Gallagher et al., 2010; Ghisalberti, 1995; Zwenger and Basu, 2008).

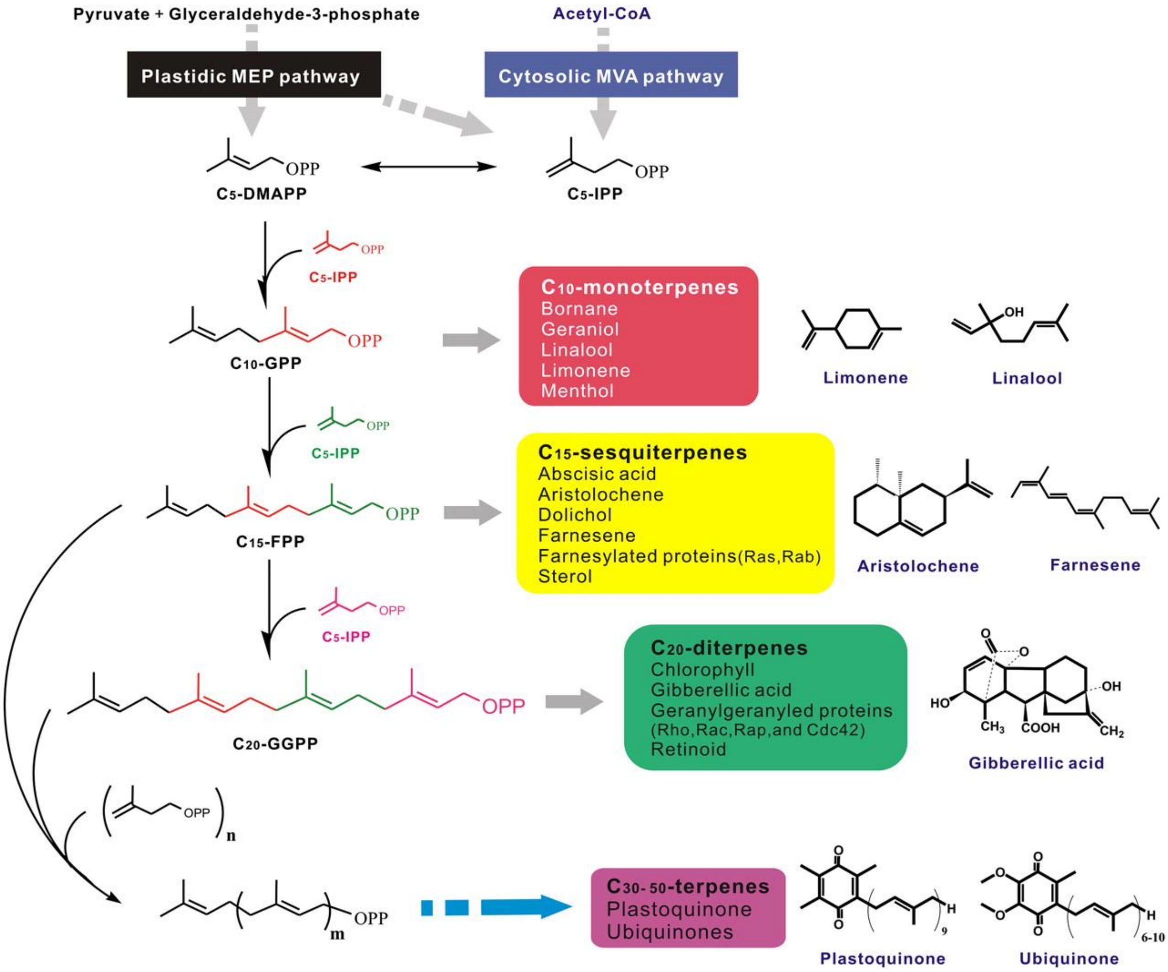
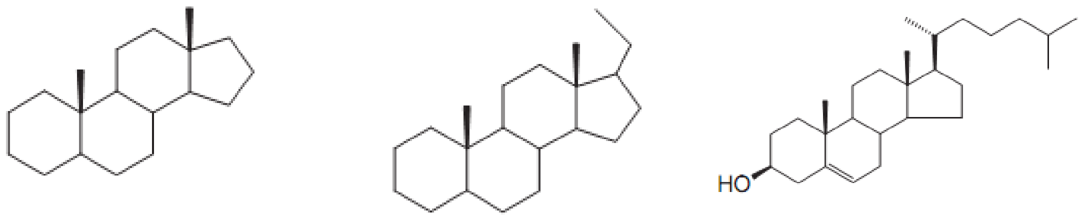


Figure I.6. Biosynthesis and Different Classes of Terpenoids

III.2.3.2.1 Steroids

Plant steroids, generally termed phytosterols, are integral components of the membrane lipid bilayer in plants. They regulate membrane fluidity, influencing the membrane's properties, functions, and structure. They contain a specific arrangement of four cycloalkane rings that are joined to each other (Li et al., 2018).

Hundreds of distinct steroids have been identified in plants, animals, and fungi, and most of them have interesting biological activity, such as growth and development, cell division, and resistance to damage from environmental stresses like cold weather. Some plant steroids are also useful for their effects when consumed by human beings because their presence decreases the amount of cholesterol in the bloodstream (Bhat et al., 2005; SH, 2018).



A C19 steroid (Androstane)	**A C21 steroid (Pregnane)**	**A C27 sterol (Cholesterol)**

Figure I.7. Chemical Structures of Some Steroids

III.2.3.2.2. Saponins

Saponins are high-molecular-weight glycosides, consisting of a sugar moiety linked to a triterpene or steroid aglycone (Singh and Chaudhuri, 2018). The classical definition of saponins is based on their surface activity; many saponins have detergent properties, give stable foams in water, show hemolytic activity, and have a bitter taste (Coulson, 1958; Rijai, 2017). However, because of the numerous exceptions which exist, saponins are now more conveniently defined based on their molecular structure, namely as triterpene or steroid glycosides (Cheriti, Babadjamian, and Balansard, 1994; Hostettmann and Marston, 1995).

Saponins are constituents of many plant drugs, they have been shown to have many biological and pharmacological functions such as hemolysis, pesticidal, cardiotonic, hypoglycemic, hypocholesterolemic, immunomodulatory, hepato-protective, anti-inflammatory, antioxidant, and anticarcinogenic activities (Coulson, 1958; Rijai, 2017; Uddin et al., 2018; Yoshikawa and Matsuda, 2006b).

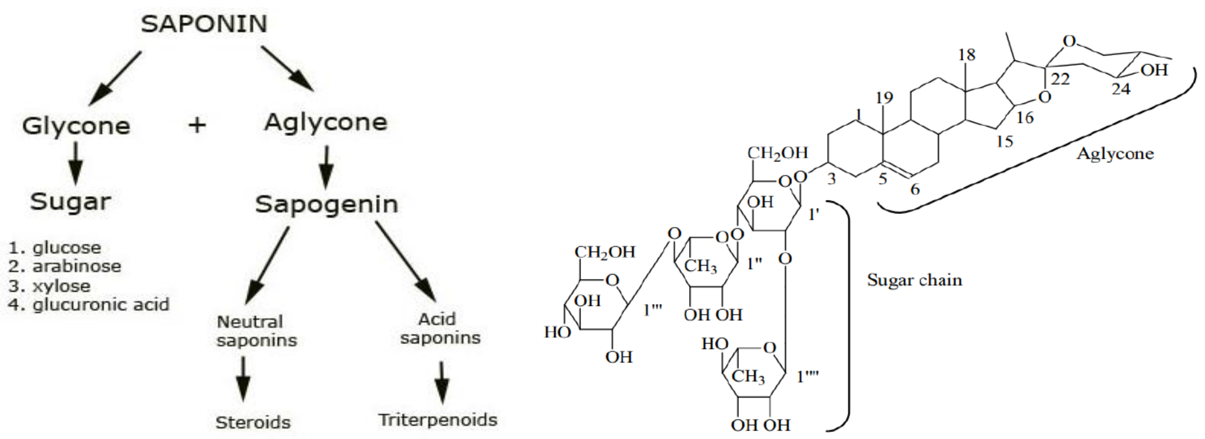


Figure I.8. Chemical Structures of Saponins

III.2.3.2.3. Essential oils

Essential oils are natural, volatile, complex plant compounds, oily or lipid-like, and frequently characterized by a strong fragrance. They are stored in specialized plant cells, usually oil cells or ducts, resin ducts, glands, or trichomes (glandular hairs) and may be extracted from the leaves, flowers, buds, seeds, fruits, roots, wood, or bark of plants by a variety of methods (Parry, 1908; Sell, 2010).

There are more than 3,000 essential oils that are physically and chemically characterized, about 150 of which are manufactured on an industrial scale (Butnariu and Sarac, 2018). Chemically, essential oils may contain up to approximately 100 components, although many contain about 20 to 60 (Carson and Hammer, 2011; Pott, Osorio and Vallarino, 2019).

Essential oils and their constituents were utilized to treat a large number of human diseases since ancient times. They could be used in different modes, it could be applied on burns, skin and muscular problems, inhalation of respiratory tract infection and physiological effect, and it can also be used for intestinal complaints (Butnariu and Sarac, 2018; Lingan, 2018; Pott et al., 2019).

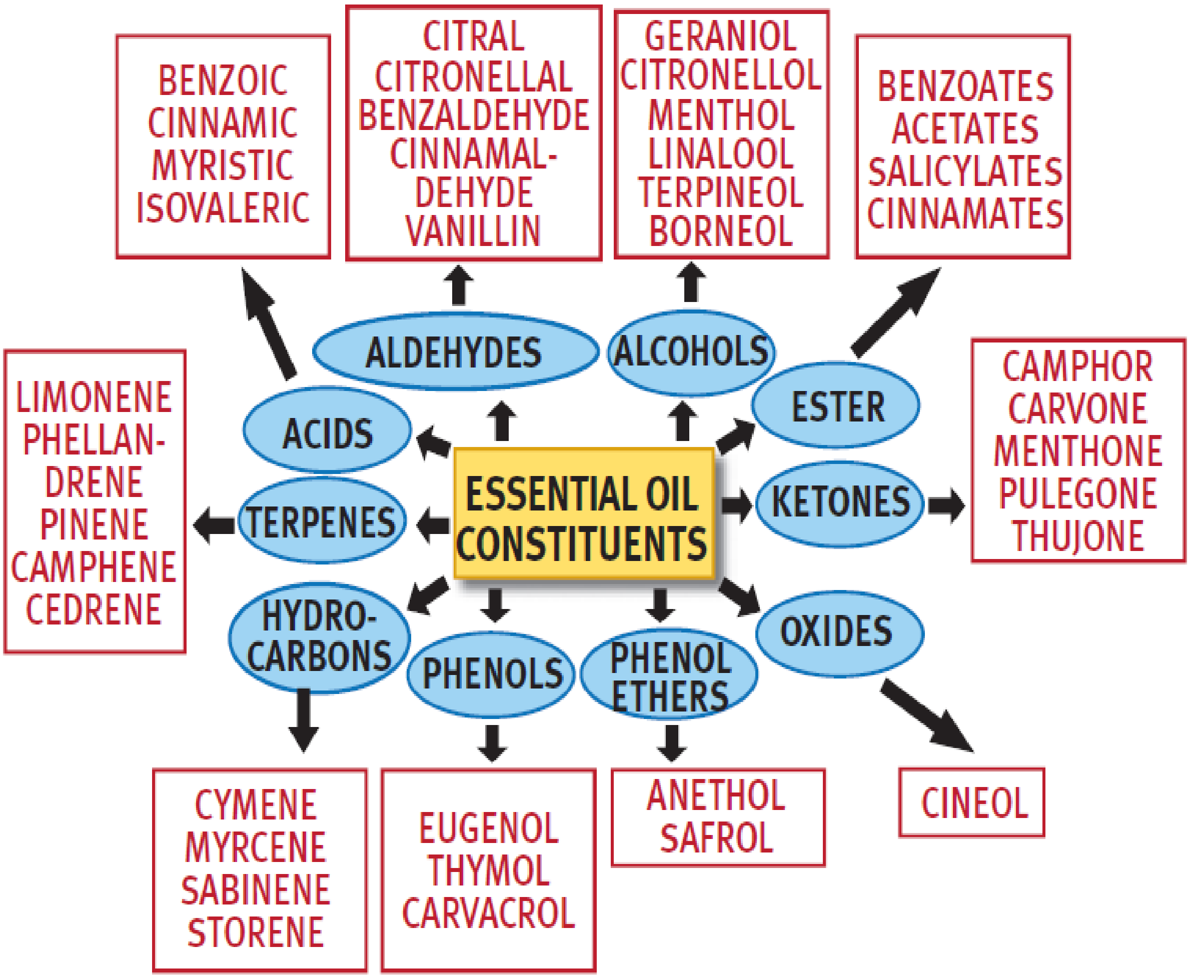


Figure I.9. Heterogeneous Chemical Groups Present in Essential Oil

III.2.3.3. Phenolics

Phenolic compounds are commonly known as plant secondary metabolites that hold an aromatic ring bearing at least one hydroxyl group. More than 8,000 phenolic compounds as naturally occurring substances from plants have been reported (Andrés-Lacueva et al., 2010; Tungmunnithum et al., 2018).

These phytochemical substances are presented in nutrients and herbal medicines and have been reported on their effective antioxidants, anticancer, antibacterial, cardioprotective agents, anti-inflammation, immune system promoting, skin protection from UV radiation, and interesting candidate for pharmaceutical and medical application (Barron, 2008; Cadot et al., 2011; Dai and Mumper, 2010; Działo et al., 2016; Torane et al., 2011; Tungmunnithum et al., 2018).

Table I.2. Most Important Classes of Phenolic Compounds in Plants

Class	Number of C-atoms	Basic skeleton
Simple Phenols, Benzoquinones	6	C6
Phenolic Acids	7	C6 - C1
Acetophenone, Phenylacetic Acid	8	C6 - C2
Hydroxycinnamic Acid, Polypropene, Coumarin, Isocoumarin	9	C6 - C3
Naphtoquinone	10	C6 - C4
Xanthone	13	C6 - C1 - C6
Stilbene, Anthrachinone	14	C6 - C2 - C6
Flavonoids, Isoflavonoids	15	C6 - C3 - C6
Lignans, Neolignans	18	(C6 - C3)2
Biflavonoids	30	(C6 - C3 - C6)2
Lignins **Catecholmelanine** **(condensed tannins)**	n	(C6 - C3)n (C6)n (C6 - C3 - C6)n

III.2.3.3.1. Lignins (Phenylpropanoids)

Lignins, also named phenylpropanoids, are widespread in higher plants, especially in the plants that produce essential oils (Korkina et al., 2011; Zaghloul et al., 2010). They are aromatic compounds with a propyl side chain attached to the benzene ring, which can be derived directly from phenylalanine (Dimmel, 2010; Petersen, Hans, and Matern, 2010; Kim, Seong, and Youn, 2011).

Lignin has diverse pharmacological activities, such as anti-tumor, antimicrobial, anti-HIV, and antioxidant activities; however, in contrast to polysaccharide-based materials, lignin has not yet been exploited significantly in the biomedical field (Spiridon, 2018).

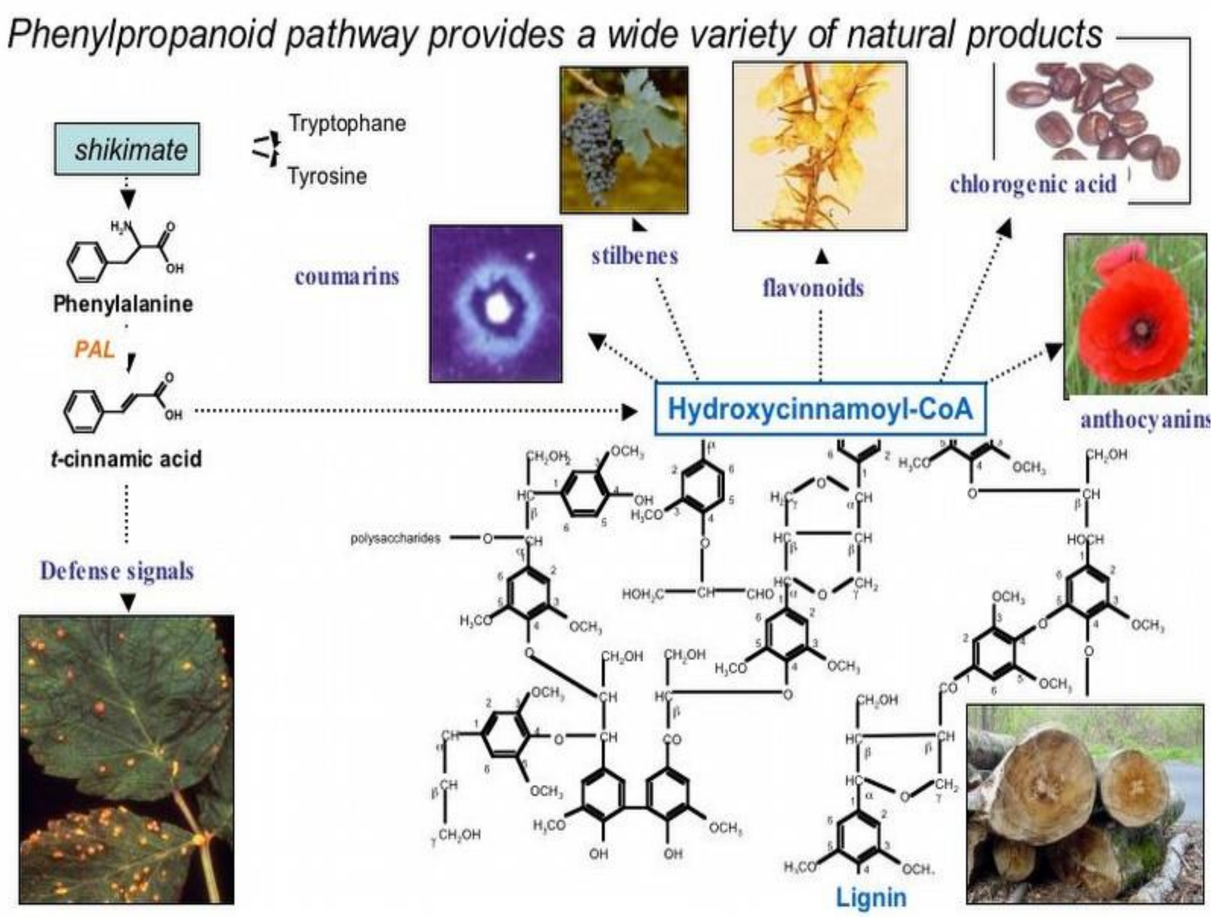
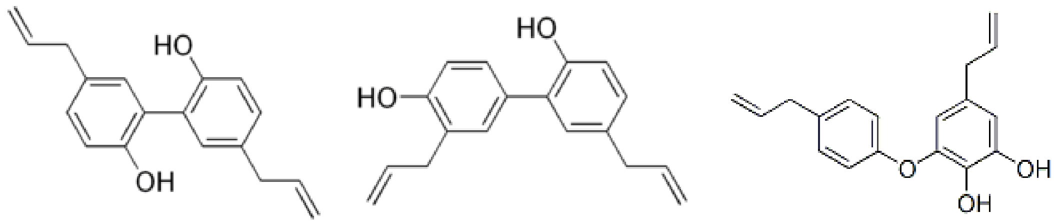


Figure I.10. Phenylpropanoid pathway

III.2.3.3.2. Lignans

Lignans are a class of secondary metabolites that are derived from the oxidative dimerization of two or more phenylpropanoid units. They are quite widespread in the plant kingdom. Natural lignans are optically active, although a few *Meso compounds* exist in nature (Deyama and Nishibe, 2010; Durazzo et al., 2018; Gohari et al., 2011; Runeberg et al., 2019; Saguez et al., 2013; Xiong et al., 2011).

Like any other optically active compounds, this class of compound has exhibited several potent, significant, biological activities, including anticancer, antimicrobial, antiviral, immunosuppressive, anti-inflammatory, antioxidant, and hepaprotective actions as well as cancer and osteoporosis prevention properties; activities that have contributed an ever-increasing interest in lignans and their synthesis (Durazzo et al., 2018; Parhoodeh et al., 2011; Pilkington, 2018; Runeberg et al., 2019).



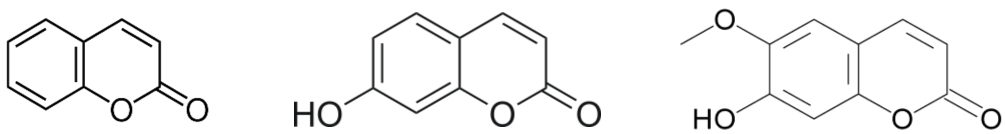
Magnolol **Honokiol** **Obovatol**

Figure I.11. Chemical Structures of Some Lignans

III.2.3.3.3. Coumarins

Coumarins are simple phenolic compounds, widespread in vascular plants and appear to function in different capacities in various plant defense mechanisms against insect herbivores and fungi (Shakeel-u-Reehana *et al.*, 2010; Verdía, Santamarta, and Tojo, 2011).

Various pharmaceutical characteristics of coumarin have also been reported, which include anti-inflammatory, anticoagulant, antibacterial, antifungal, antiviral, anticancer, anti-hypertensive, antitubercular, anticonvulsant, anti-adipogenic, antioxidant, and neuroprotective properties (Sarker and Nahar, 2013; Hussain, Qamar Abbas, and Reigosa, 2018; Mustafa, Najem and Tawffiq, 2018; Widelski et al., 2018).



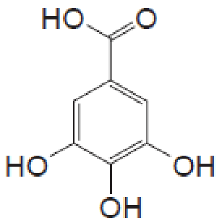
Coumarin **Umbelliferone** **Scopoletin**

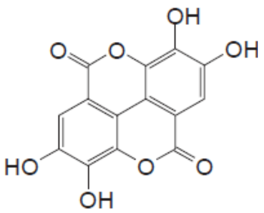
Figure I.12. Chemical Structures of Some Coumarins

III.2.3.3.4. Tannins

Tannins are the most abundant secondary metabolites in plants. They consist of various phenolic compounds that react with proteins to form water-insoluble copolymers. Plant tissues that are high in tannin content have a highly bitter taste and are avoided by most feeders. This class may be either condensed or hydrolysable. Condensed tannins are formed biosynthetically by the condensation of catechins to form polymeric networks. Hydrolysable tannins are derived from gallic acid (Cseke et al., 2016).

Tannins have a wide range of biological and pharmacological activities including antioxidative, anticarcinogenic, anti-inflammatory, antibacterial, cardioprotective, and anti-mutagenic activities (Hu et al., 2018).





Gallic acid **Ellagic acid**

Figure I.13. Chemical Structures of Two Important Tannins

III.2.3.3.5. Flavonoids

The flavonoids are a diverse group of polyphenolic compounds widely distributed in the plant kingdom and over 4,000 structurally unique flavonoids have been identified in plant sources. Flavonoids have a skeleton of diphenylpropanes, two benzene rings (A and B) connected by a three-carbon chain forming a closed pyran ring with the benzene A ring. In plants, they usually occur glycosylated mainly with glucose or rhamnose, but they can also be linked with galactose, arabinose, xylose, glucuronic acid, or other sugars (Brodowska, 2017; Chemler et al., 2009; Jaganath and Crozier, 2010; Jain et al., 2019; Saltveit, 2010).

Flavonoids may be divided into six different major classes based on differences in molecular backbone structure (Tsao and Mccallum, 2009):

Flavonols and **flavones** have a double bond between C2 and C3 in the flavonoid structure and an oxygen atom at the C4 position. Furthermore, flavonols also have a hydroxyl group at the C3 position.

Dihydroflavonols have the same structure as flavonols without the double bond between C2 and C3 (Terao, 2010).

Flavanones are represented by the saturated three-carbon chain and an oxygen atom in the C4 position.

Isoflavones also have a diphenyl propane structure in which the B ring is located in the C3 position. They have structural analogies to estrogens, such as estradiol, with hydroxyl groups at the C7 and C4 positions (Pang, Tian, and Dixon, 2008; Franke *et al.*, 2010).

Anthocyanins are based on the flavylium salt structure and are water-soluble pigments in plants. They are found in the form of glycosides in plants and foods of their respective aglycones, called anthocyanidins (Andersen, 2008; Mazza and Kay, 2008).

Flavanols or **flavan-3-ols** have a saturated three-carbon chain with a hydroxyl group in the C3 position. In foods, they are present as monomers or as proanthocyanidins, which are polymeric flavanols (4 to 11 units) known also as condensed tannins (Brodowska, 2017; Pérez-Vizcaíno and Duarte, 2009).

These are primarily recognized as the pigments responsible for the many shades of yellow, orange, and red of flowers, fruit, and leaves. These natural products were known for their beneficial effects on health long before they were isolated as effective compounds (Patel, 2008).

Table I.3. Most Important Classes of Flavonoids and their Biological Significance

Class	Biological Significance
Anthocyanin(s)	Red and blue pigments
Chalcon	Yellow pigments
Aurones	Yellow pigments
Flavones	Cream-colored pigments of flowers
Flavonols	Feeding repellents in leaves
Dihydrochalcone	Some taste bitter
Proanthocyanidins	Astringent substances
Catechins	Some have properties like those of tannins
Isoflavonoids	Oestrogen effect, toxic for fungi

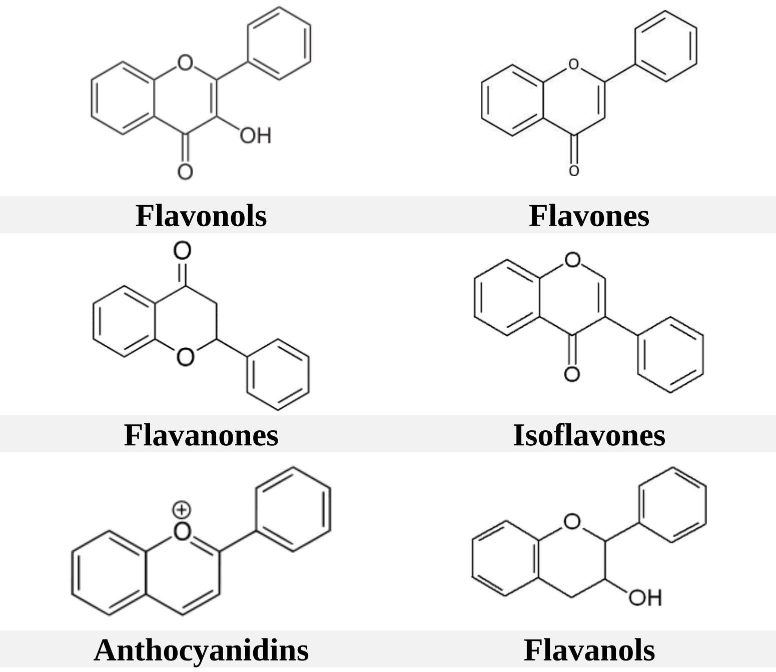


Figure I.14. Typical Flavonoid Subgroups

III.3. Plant-Derived Compounds Role in Drug Development

Despite the recent interest in drug discovery by molecular modeling, combinatorial chemistry, and other synthetic chemistry methods, natural-product-derived compounds are still proving to be an invaluable source of medicines for humans (Banerji, 1992; Danjuma et al., 2009; Jain et al., 2019).

The importance of plants in modern medicine has been discussed earlier. Other than the direct usage of plant secondary metabolites in their original forms as drugs, these compounds can also be used as drug precursors, templates for synthetic modification, and pharmacological probes (Jain et al., 2019; Nishad et al., 2018; Sagadevan et al., 2019).

III.4. Natural Products Identification

Recently, natural products chemistry has undergone explosive growth due to advances in isolation techniques, synthetic and biosynthetic approaches as well as spectroscopic and chromatographic methods (Cahlíková et al., 2020; Ikan, 2008; Jain et al., 2019).

Modern methods used to separate complex organic mixtures utilizing gas-liquid Chromatography (GLC), high-pressure liquid chromatography (HPLC), and droplet counter-current (DCC) chromatography can separate samples rapidly and efficiently in the pictogram range. This has been impossible until recently (Dias, Urban, and Roessner, 2012; Cahlíková *et al.*, 2020).

Coupling the chromatographic instruments to spectrometers enables a partially automated analysis in an even shorter period. The following coupling of chromatographic instruments has been performed: GC-MS, GC-FTIR, GC-MI-FTIR, GC-UV-VIS, HPLC-MS, HPLC-FTIR, HPLC-FTNMR, and MS-MS (Colegate and Molyneux, 2008; Hostettmann and Wolfender, 2001).

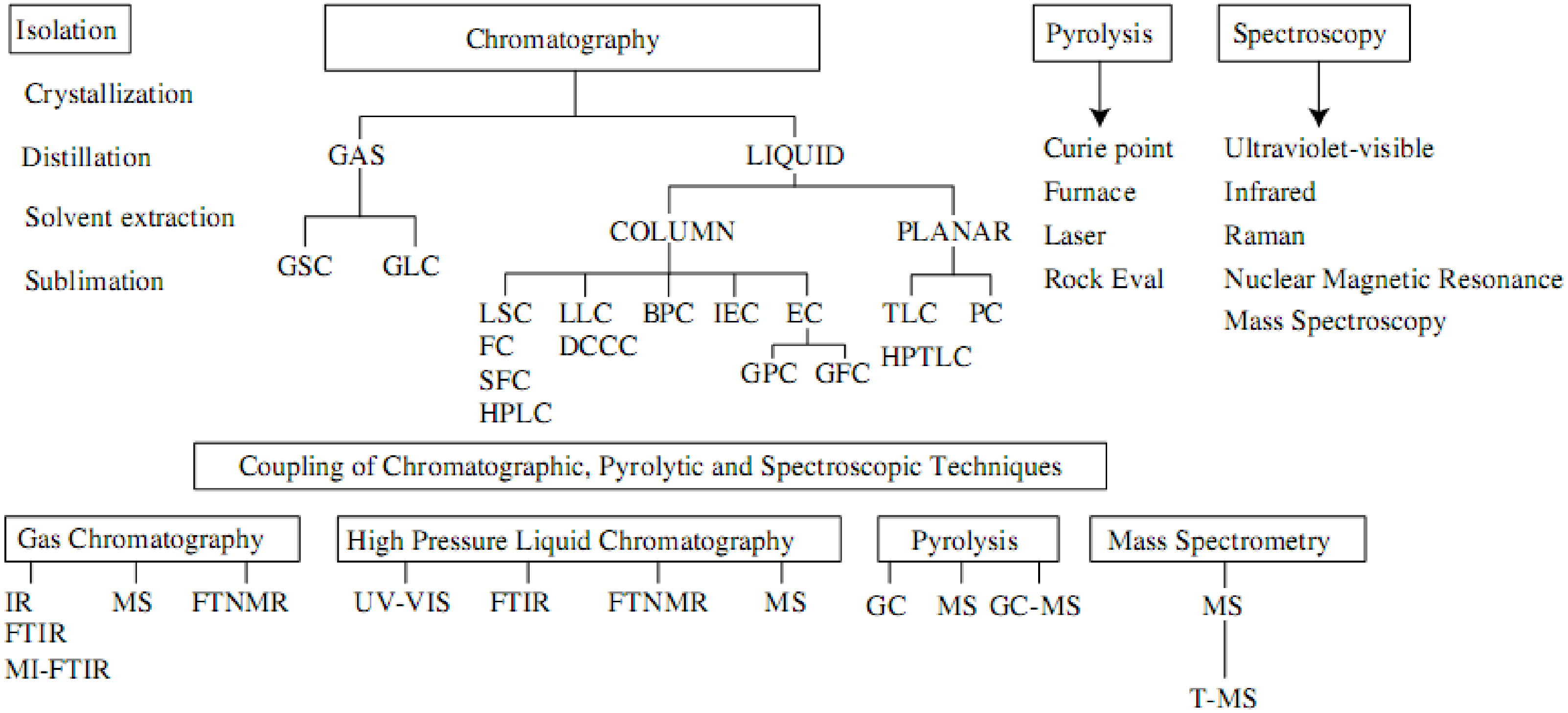


Figure I.15. Chromatographic and Spectroscopic Techniques

GC, gas chromatography; **GLC**, gas–liquid chromatography; **GSC**, gas-solid chromatography; **TLC**, thin-layer chromatography; **HPTLC**, high-performance thin-layer chromatography; **PC**, paper chromatography; **LSC**, liquid–solid chromatography; **FC**, flash chromatography; **SFC**, supercritical fluid chromatography; **LLC**, liquid–liquid chromatography; **DCCC**, droplet counter-current chromatography; **PBC**, bonded phase chromatography; **HPLC**, high-pressure liquid chromatography; **IEC**, ion-exchange chromatography; **EC**, exclusion chromatography; **GPC**, gel permeation chromatography; **GFC**, gel filtration chromatography; **IR**, infrared; **UV**, ultraviolet; **NMR**, nuclear magnetic resonance; **MS**, mass spectroscopy; **FT**, Fourier transform; **T-MS**, Tandem mass spectroscopy; **MI-FTIR**, matrix isolation Fourier transform infrared.

III.5. Plant Products as Antioxidants

An antioxidant can be defined as “any substance that delays, prevents or removes oxidative damage to a target molecule” or “any substance that directly scavenges reactive oxygen species (ROS) or indirectly acts to up-regulate antioxidant defenses or inhibit ROS production” (Sagadevan et al., 2019; Victoria Urquiza-Martínez and Fenton Navarro, 2016).

The human body produces many enzymatic and no enzymatic endogenous antioxidants to provide the primary defense against superoxide and hydrogen peroxides (Nimalaratne and Wu, 2015; Nimse, and Pal, 2015). Hence, it's very important to find normal alternative antioxidants with high safety (Jain, Vijayvergia, and Khatana, 2019; Sagadevan *et al.*, 2019).

Antioxidants originated from natural plant sources are more potent and safer due to their harmless nature. Plant natural products are being extensively used as antioxidants for their capacity to protect organisms and cells from oxidative damage (Sagadevan et al., 2019).

The most known groups of natural antioxidants are vitamin A, vitamin C, vitamin E, carotenoids, polyphenols (ellagic acid, gallic acid, and tannins), flavonoids (flavones, isoflavones, flavonoes, anthocyanins, and catechins) and more recently, peptides with antioxidant properties derived from various plant and animal sources (Abba *et al.*, 2015; Pezeshk, Ojagh, and Alishahi, 2015; Labiad *et al.*, 2017). Most of these plant-derived, antioxidant compounds have significant antioxidant activities because of their strong capacity to donate electrons or hydrogen atoms and can directly scavenge ROS (Mehta and Gowder, 2015; Nimalaratne and Wu, 2015; Sagadevan et al., 2019).

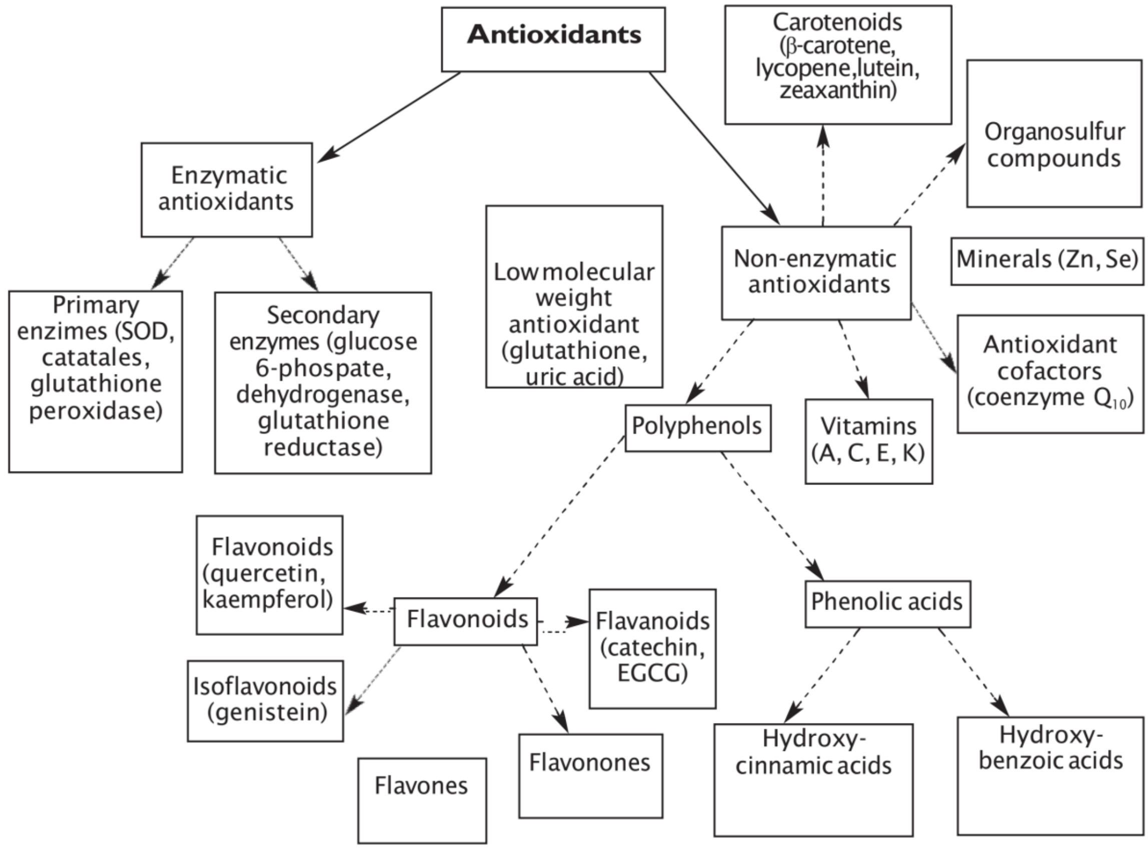


Figure I.16. Antioxidants Classification

The benefit of antioxidant uptake has been demonstrated in the course of some diseases and certain conditions, like diabetes, asthma, hemodialysis, thalassemia, rheumatoid arthritis, systemic attack, postmenopause, schizophrenia, depression, and leukemia by decreasing localized oxygen concentration; preventing chain initiation, by scavenging radicals; decomposing lipid peroxides to peroxyl and alkoxyl radicals; decomposing peroxides by converting them to non-radical products, and chain-breaking to prevent continued hydrogen abstraction (Mut-Salud et al., 2016; Rawat et al., 2016; Slezák et al., 2016; Sultan, 2014).

Moreover, the study of antioxidants use in cancer treatment is a rapidly evolving area (Nepomuceno, 2011). The importance of antioxidants is underlined by a recent study that estimates 23% of cancer patients take antioxidants and there is a possibility that diets that are rich in antioxidants can reduce the incidence of cancer. Most of the papers hereby reviewed and checked the potency and efficiency of antioxidants in treating neurodegenerative diseases and cancer therapy (Gummadi, 2016; Mut-Salud et al., 2016; Sagadevan et al., 2019).

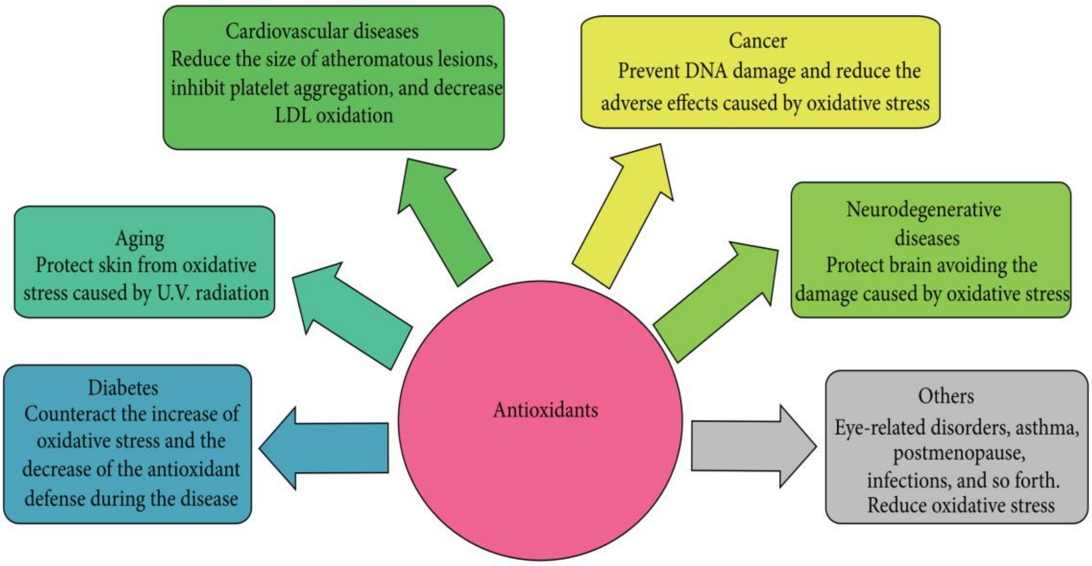


Figure I.17. Influence of Antioxidants on Human Health

III.6. Plant Products as Antimicrobial Agents

The random and the increasing uses of commercial antimicrobial drugs in the treatment of infectious diseases developed resistance against several of these drugs (Vandal et al., 2015). In addition, antibiotics are sometimes associated with adverse side effects on the host correlated with hypersensitivity, depletion of the beneficial gut and mucosal microorganisms, immune suppression, and allergic reactions (Cardoso et al., 2019; Uddandapu et al., 2016).

Recently, the world's attention aims to find new effective and safe antimicrobials from plants that can consequently be considered in the development of new drugs to combat problems associated with drug resistance (Vandal *et al.*, 2015; Cardoso, de Oliveira, and Cardoso, 2019). Using effective plant extracts to control human diseases has the additional advantage of low production cost, minimal environmental damage, and higher accessibility to rural communities (Teka et al., 2015).

The secondary metabolites of plants exhibit several benefits including antimicrobial properties against pathogenic and spoilage microbes (Arumugam, Swamy, and, Sinniah, 2016). It was shown that the variations in the chemical composition of these compounds lead to differences in their antimicrobial action. For instance, the site and number of hydroxyl groups on the phenolic compounds are thought to be related to their relative toxicity to microorganisms (Bogner et al., 2017).

Existing evidence suggests that increased hydroxylation results in increased toxicity owing to the formation of intramolecular hydrogen bridges, which increase the lipophilic character, and thus, allow for easier penetration through the cell wall (Gogoi et al., 2016). In addition, some authors have found that most of the highly oxidized phenols are inhibitory. The mechanisms thought to be responsible for phenolic toxicity to microorganisms include enzyme inhibition by the oxidized compounds, possibly through reaction with sulfhydryl groups or through more nonspecific interactions with the proteins (Chainani et al., 2015).

Since Flavonoids are known to be synthesized by plants in response to microbial infection, it should not be surprising that they have been found *in vitro* to be effective anti-microbial substances against a wide array of microorganisms. Their activity is probably due to their ability to complex with extracellular and soluble proteins and to complex with bacterial cell walls (Tripathi and Tiwari, 2015). Numerous studies have also documented their effectiveness against HIV (Brodowska, 2017).

Tannins have received a great deal of attention in recent years since it was suggested that the consumption of tannin-containing can cure or prevent a variety of illnesses. Many human physiological activities, such as stimulation of phagocytic cells, host-mediated tumor activity, and a wide range of anti-infective actions, have been assigned to tannins (Anionye and Onyeneke, 2016; Korlam and Murthy, 2016). One of their molecular actions is too complex with proteins through so-called nonspecific forces such as hydrogen bonding and hydrophobic effects, as well as by covalent bond formation. Thus, their mode of antimicrobial action may be related to their ability to inactivate microbial adhesins, enzymes, and cell envelope transport proteins (Shanmugavel and Krishnamoorthy, 2015).

Terpenoids and Essential Oils are also active against bacteria, fungi, viruses, and protozoa. In 1977, it was reported that 60% of essential oil derivatives examined to date were inhibitory to fungi while 30% inhibited bacteria. the mechanism of action of terpenes is not fully understood but is speculated to involve membrane disruption by the lipophilic compounds (Saraf and Samant, 2015). It is also found that terpenoids can also prevent the formulation of ulcers and diminish the severity of existent ulcers (Uddandapu et al., 2016; Uma and Sekar, 2014).

Various mechanisms have been proposed for the antimicrobial activities of natural antimicrobials. Considering a large number of different groups of chemical compounds present in the extracts of natural products, it is most likely that their antimicrobial activity is not attributable to one specific mechanism but that there are several targets in the cell. Phytochemicals can act by disrupting microbial membranes or impairing cellular metabolism. They can also control biofilm formation. Plant antimicrobials can inhibit bacterial capsule production. Some plant compounds can attenuate bacterial virulence by controlling quorum-sensing.

Another mechanism of plant metabolites' antimicrobial action is the reduction of microbial toxin production. Plant metabolites can also act as resistance-modifying agents. Nowadays resistance-modifying agents are considered as one of the most prospective ways to combat bacterial resistance. Some studies have already shown that plant-derived compounds can enhance the therapeutic effect of antibiotics acting as resistance-modifying agents (Ginovyan et al., 2017; Gogoi et al., 2016; Hintz et al., 2015; Park, 2015).

Table I.4. Mechanism of Action of Some Important Phytochemicals (Jain et al., 2019; Uddandapu et al., 2016; Uma and Sekar, 2014)

Phytochemicals	Activity	Mechanism of action
Flavonoids	Antimicrobial Antidiarrheal	➲ Complex with cell walls binds to adhesions. ➲ Inhibits release of autacoids and prostaglandins. ➲ Inhibits contractions caused by spasm gens. ➲ Stimulates normalization of the deranged water transport across the mucosal cells. ➲ Inhibits GI release of acetylcholine.
Terpenoids and essential oils	Antimicrobial Antidiarrheal	➲ Membrane disruption. ➲ Inhibits release of autacoids and prostaglandins.
Alkaloids	Antimicrobial Antidiarrheal Anthelmintic	➲ Intercalates into cell wall and DNA of parasites. ➲ Inhibits release of autacoids and prostaglandins. ➲ Possess anti-oxidizing effects. ➲ Suppresses transfer of sucrose from the stomach to the small intestine. ➲ Diminishing the support of glucose to the helminths. ➲ Acts on CNS, causing paralysis
Lectins and polypeptides	Antiviral	➲ Blocks viral fusion or adsorption, forms disulfide bridges.
Glycosides	Antidiarrheal	➲ Inhibits release of autacoids and prostaglandins.
Saponins	Anticancer Anthelmintic Antidiarrheal	➲ Possesses membrane permeabilizing properties. ➲ Leads to vacuolization and disintegration of teguments. ➲ Inhibits histamine release *in vitro*
Steroids	Antidiarrheal	➲ Enhance intestinal absorption of Na+ and water.

IV. EXPERIMENTAL PLANTS

The southwest Algerian flora is very rich and a great number of species have been used traditionally for the treatment of several diseases without any scientific background (Deena and Thoppil, 2000; Fatehi et al., 2017).

Of the shrub and tree species encountered in the desert of southwest Algeria, nine of the most popular medicinal plant species frequently used in the local traditional medicine in the Bechar region are subjected in this study, namely *Andropogon nardus* L., *Andropogon schoenanthus* L., *Globularia alypum* L., two species of *Hammada scoparia* Pomel., *Periploca laevigata* Ait., *Rhus tripartita* R. Sch., *Tamarix gallica* L. and *Traganum nudatum* Del.

IV.1. *Andropogon nardus* L.

Andropogon nardus (Poaceae), locally known as “Lidkhir” and generically named as grasses, belongs to (Gramineae), a very large plant family that comprises approximately 700 genera and 12.000 herb species (Soenarko, 1977; Vasil, 1995; Watson and Dallwitz, 1992).

A. nardus is a perennial grass; erect, growing in thick tufts, branched rhizome. Leaf-blades are linear, glabrous, aromatic; having ligule ovate, truncate, about 2 mm longpubescentnt; sheath persistent, basal ones imbricate, curling up when dry. The inflorescence is in a large panicle up to 80 cm long; each spike consists of 4-5 spikelets, rach,is and pedicels ciliate, funnel-shaped. Spikelets arpairsir, one is sessile the other is pedicelled (Farnsworth and Bunyapraphatsō̦n, 1992; Reitz, 1982).

A. nardus is largely found in North Africa (Algeria, Egypt, Libya, Morocco), the Middle East (Iraq, Oman, Saudi Arabia, and Yemen), and many other places in tropical Asia (Quattrocchi, 2016).

IV.1.1. Taxonomic Classification

Kingdom	**Plantae**
Division	Magnoliophyta
Class	Liliopsida
Subclass	Commelinidae
Order	Cyperales
Family	Poaceae
Genus	*Andropogon*
Species	*A. nardus* L.
Binomial Name	*Andropogon nardus* L.

Figure I.18. *Andropogon nardus* L.

IV.1.2. Synonyms

Andropogon martinii Roxb., *Cymbopogon martini* (Roxb.) W. Watson, *Cymbopogon pospischilii* (K. Schum.) C. E. Hubb., *Cymbopogon stracheyi* (Hook. f.) Raizada & S. K. Jain, *Cymbopogon nardus* (L.) Rendle.

IV.1.3. Vernacular Names

Arabic: Lidkhir (Algeria, Morocco), Othkhor (Middle East) ليدخير، الاذخر

French: Citronnelle, Citronelle de Ceylan

English: Ceylon citronella, Citronella, Citronella grass, Lemon grass.

IV.1.4. Traditional Uses

A. nardus is recorded in the literature to have folkloric uses. For instance, in Nigeria, it is used as an antipyretic, and for its stimulating and antispasmodic effects (Olaniyi, Sofowora, and Oguntimehin, 1975). In India, it is used for gastrointestinal problems, in China, as ansiolitic, and in Indonesia, this plant is indicated to help digestion, to promote diuresis, and sweating (Alves and Souza, 1960; Hirschhorn, 1983; Peigen, 1983). In some other places, it is commonly used to treat flu, fever, pneumonia, and to solve gastric and sudorific problems. Besides the medicinal use, its essential oil is also used in the food (flavoring), perfume and cosmetics industries (Lorenzetti et al., 1991; Thappa et al., 1971).

IV.1.5. Pharmaceutical Interests

From the leaves, its oil is reached in citral and other terpenes, such as myrcene. Due to its easy polymerization, myrcene is responsible for the early deterioration of the oil. Pure citral is isolated from the oil and used as a key raw material in the manufacture of vitamin A. The essential oil shows significant antimalarial activity (Koba et al., 2004; Mosquera, 2016; Tchoumbougnang et al., 2005). Positive results such as antiprotozoal, anti-inflammatory, antimicrobial, antibacterial, antidiabetic, anticholinesterase, molluscicidal, antifungal, and larvicidal activity are also prominent with this kind of species (Avoseh et al., 2015; Brugnera et al., 2011; Djukic et al., 2016; Ganjewala, 2009; Sonawane et al., 2008).

IV.1.6. Phytochemical Constituents

According to the latest research, several natural compounds were isolated from *Andropogon nardus*. These studies have been revealing that although the chemical composition varies according to the geographical origin, the compounds such as hydrocarbon terpenes, alcohols, ketones, esters, and mainly aldehydes, have constantly been registered (Costa, 1986; Trease, 1996).

Among the several isolated and identified substances from leaves and roots, there are alkaloids, saponin, terpenes, alcohols, ketone, flavonoids, cholorogenic acid, caffeic acid, p-coumaric acid, and sugars (Olaniyi et al., 1975).

The total amount of essential oil obtained from this genus varied between 0.28 and 1.4%. A wide number of phytoconstituents have been identified in the essential oil of *A. nardus*, such as; citronellal (35%), geraniol (25%), and citronellol (10%) plus minor amounts of geranyl acetate (5%) (Abutalib et al., 2015; Brugnera et al., 2011; Djukic et al., 2016; Ganjewala, 2009; Koba et al., 2004; Mahboubi and Kazempour, 2014; Stone et al., 2013).

IV.2. *Andropogon schoenanthus* L.

Andropogon schoenanthus (Poaceae), locally known as "Lemmad", is a glabrous compactly tufted much-branched perennial herbs up to 60 cm high, with slender, erect, 3-4 nodded culms. Leaves alternate; laminas linear, 10-30 x 3 cm, tapering to a long setaceous point; ligule membranous, ciliolate, truncate; sheath 5-8 cm long, firm. Inflorescences spatheate panicle, 6-20 x 3-5 cm; spathes lanceolate, apex acuminate, up to 2.5 cm long (Quattrocchi, 2016; Zhong and Chen, 2019).

A. schoenanthus was native to tropical Asia especially India, However, As a characteristic desert plant, it occurs throughout North Africa (Algeria, Egypt, Libya, Morocco, Sudan), Sub-Saharan regions (Chad, Djibouti, Ethiopia, Somalia, Kenya, Benin, Burkina Faso, Ghana, Guinea, Mali, Mauritania, Niger, Nigeria, Senegal, and Togo) and Asia (Iraq, Oman, Saudi Arabia, and Yemen) (Amina et al., 2013; Benhouhou et al., 2003; El Ghazali et al., 1997; Ernest J. Parry, 1921; Zhong and Chen, 2019).

IV.2.1. Taxonomic Classification

Kingdom	**Plantae**
Division	Magnoliophyta
Class	Liliopsida
Order	Cyperales
Family	Poaceae
Genus	*Andropogon*
Species	*A. schoenanthus* L.
Binomial Name	*Andropogon schoenanthus* L.

Figure I.19. *Andropogon schoenanthus L.*

IV.2.2. Synonyms

Andropogon circinnatus Hochst. ex Steud., *Andropogon eriophorus* Willd., *Andropogon ivarancusa* Boiss., *Andropogon iwarancusa* subsp. *Laniger*, *Andropogon lanigerum* Desf., *Andropogon mascatensis* G., *Andropogon nardoides* Nees., *Andropogon versicolor*, *Cymbopogon circinnatus*, *Cymbopogon schoenanthus* (L.) Spreng., *Cymbopogon versicolor*, *Sorghum schoenanthus* (L.) Kuntze, *Trachypogon schoenanthus* (L.) Nees.

IV.2.3. Vernacular Names

Arabic: Lemmad (Algeria, Morocco), Othkhor l'makki (Middle East) اللماد، الاذخر المكي
French : schoenanthe officinale, Herbe des chameaux, paille de la Mecque.
English: Camel grass, Geranium grass, Camel hay grass, Lemon-scented grass.

IV.2.4. Traditional uses

A. schoenanthus is used in traditional medicine as antihelminthes, antidiarrhea, antirheumatic, carminative, diaphoretic, stomachic, diuretic, emenagogue, antipyretic, for treatment of jaundice and as a tonic. It was also used for anorexia; astringent, sudorific and to cure dromedary wounds (Marwat et al., 2009).

In south Algeria, the plant is particularly appreciated for its medicinal values and is well known to bring back the appetite. It is taken as a diuretic; cures intestinal troubles and food poisoning and helps digestion.

In Morocco and Egypt, an infusion of the flowers and the whole plant was used as febrifugal, diuretic, antirheumatismal, and antigastralgic. The plant was used in Sudan for the treatment of gout, prostate inflammation, kidney diseases, and stomach pains (Benchelah et al., 2000).

IV.2.5. Pharmaceutical Interests

A. schoenanthus essential oil, called Palmarosa oil, is valued for its scent and a number of pharmaceutical interests. It is an anthelmintic, antiseptic, antispasmodic, aphrodisiac, astringent, emmenagogue, insectifuge, nematicide, stimulant sudorific, and vulnerary (Amina et al., 2013; Avoseh et al., 2015; Heiba and Rizk, 1986; Zhong and Chen, 2019).

IV.2.6. Phytochemical Constituents

Chemical analysis showed that *A. schoenanthus* contained tannins, saponins, saponin glycosides, flavonoids, alkaloids, triterpenes, cardiac glycosides, glycosides, steroids, and volatile oils (Ahmed et al., 2010; Avoseh et al., 2015). The major components of the Essential oil of *Andropogon schoenanthus* were limonene (10.5-27.3 %), β-phellandrene (8.2-16.3 %), δ-terpinene (4.3-21.2 %), and α-terpineol (6.8-11.0 %). However, citral was one of the main constituents of many different species (Amina et al., 2013; Bothon et al., 2013; Ganjewala, 2009; Heiba and Rizk, 1986; Ketoh et al., 2006; Koba et al., 2004; Shahi and Tava, 1993).

IV.3. *Globularia alypum* L.

Globularia alypum (Globulariaceae), locally known as “Tassalgha”, is a perennial shrub, dense low evergreen mat-forming herbs, or subshrubs, with leathery oval leaves 1-10 cm long. The flowers are produced in dense inflorescences (capitula) held above the plant on a 1-30 cm tall stem; the capitula are 1-3 cm in diameter, with numerous tightly packed purple, violet, pink or white flowers (Polunin et Huxley, 1967, (Paris et Dillemann, 1960).

G. alypum is found throughout the Mediterranean area, native of central and southern Europe, Macaronesia, northwest Africa, and southwest Asia (Ben Mimoun and Nouira, 2015; Hazler Pilepić et al., 2017; Stambouli-Meziane and Bouazza, 2014)

IV.3.1. Taxonomic Classification

Kingdom	**Plantae**
Division	Magnoliophyta
Class	Magnoliopsida
Subclass	Asteridae
Order	Scropphulariales
Family	Globulariaceae
Genus	*Globularia*
Species	*G. alypum* L.
Binomial Name	*Globularia alypum* L.

Figure I.20. *Globularia alypum* L.

IV.3.2. Synonyms

Globularia alypum subsp. *murbeckii* Sennen, *Globularia alypum* subsp. *alypum* L., *Globularia turbith* Willk., *Globularia virgata* Salisb., *Alypum monspeliensium* Fourr., *Alypum salicifolium* Fisch., *Alypum solandri* hort. ex Steud.

IV.3.3. Vernacular Names

Arabic: Taselgha, âïn larneb, zriga التسلغا، عين الارنب، زريقة

French: Globulaire, turbith, Séné de provence, Herbe terrible

English: Alypo globe daisy, Globularia

IV.3.4. Traditional Uses

G. alypum is largely used in the treatment of several infectious diseases, its leaves are traditionally used as hypoglycemic agent, laxative, cholagogue, stomachic, purgative and sudorific, antihypertensive, and hypoglycemic. It is also used in the treatment of cardiovascular and renal diseases (Kara Ali et al., 2016; Khlifi et al., 2011; Mehdioui and Kahouadji, 2007; Orch et al., 2015; Raj et al., 2016).

In Algeria, *G. alypum* is traditionally used as antidiabetic, leishmanicidal, and used also for treating digestive disorders and eczema (Baghdad et al., 2016; Boudjelal et al., 2013; Chermat and Gharzouli, 2015; Fehri and Aiache, 2013; Merghache et al., 2013; Ouelbani et al., 2016; Rachid et al., 2012).

IV.3.5. Pharmaceutical Interests

The infusion of *G. alypum*, exhibiting no toxicological effects, was shown to produce a significant hypoglycemic in rats both by oral and intraperitoneal administration (Skim et al., 1999). A significant antileukemic activity of an aqueous extract of *G. alypum* was also reported (Caldes et al., 1975).

Recently, methanol and dichloromethane extracts of *G. alypum* were also shown to reduce histamine and serotonin contraction *in vitro* (Bello et al., 2002). The antioxidant activity of the *G. alypum* phytochemicals (flavonoids, phenylethanoids, iridoids) was also evaluated (Boutemak et al., 2016; Harzallah et al., 2010; Khlifi et al., 2011).

As a consequence of these properties, *G. alypum* can have immense potential in preventing oxidative damage to the heart caused by anticancer drugs (Es-Safi et al., 2005; Kara Ali et al., 2016; Merghache et al., 2013). In addition, *G. alypum* was shown to exert an anti-ulcer activity against the gastric mucosal damages caused by indomethacin that the mechanism of action may result from an inhibition of intraepithelial lymphocytes migration (Fehri and Aiache, 2013).

IV.3.6. Phytochemical Constituents

Chemical investigations carried out on *G. alypum* have reported the isolation and characterization of the major constituents: globularin and cataptol. The existence of aucubin, catalposide, monotropein, and catalpol was also reported. Four other iridoid glucosides: globularicisin, globularidin, globularimin, and globularinin, as well as the lignan diglucoside liriodendrin, and syringin have been isolated from *G. alypum* (Fehri and Aiache, 2013). More recently, a new chlorinated iridodoid glucoside and globularioside were isolated from *G. alypum* growing in Morocco (Es-Safi et al., 2006).

IV.4. *Hammada scoparia* Species

Two species of *Hammada scoparia* (Chenopodiaceae), locally known as “Remth lakhder and Remth lahmer”, are used in this study. These two species are of the few plants that are found in all seasons. They are very common in sandy habitats commonly found in highly saline patches; and characterized by their excellent tolerance to drought and salinity, distributed widely in North Africa (Bibi et al., 2010).

Hammada scoparia species are small, highly branched halophytic shrubs, C4 perennial herbs, with succulent, spindly, segmented branches, that grow no higher than 1 m (40-60 cm). Leaves are opposed, atrophied into scales, and fused onto the segment that bears them. Flowers have no petals and are dense, arranged in a terminal spike. Fruit-bearing perigone has a membranous, brilliant crown. Flowering starts in autumn and fructification ends in December (Alfarhan, 2001; Weber et al., 2007).

Globally, *Hammada scoparia* species are found mainly in North Africa (Morocco (Southern Steppes of Morocco) (Alch and Narjisse, 1990), Algeria (Maiza et al., 1993; Zabeirou et al., 2003), Tunisia (From Sousse to the far south of Tunisia (Jaouadi et al., 2016)), North Libya and Egypt (North Sinai) (Minocheherhomji, 2016)) and the Middle East (Iran, Syria, Iraq and Arabian Gulf Sahara (Brown and Porembski, 1997; Hellyer and Aspinall, 2005) … etc.).

IV.4.1. Taxonomic Classification

Kingdom	**Plantae**
Division	Magnoliophyta
Class	Magnoliopsida
Order	Caryophyllales
Family	Amaranthaceae
Subfamily	Chenopodiaceae
Genus	*Hammada*
Species	*H. Scoparia* Pomel.
Binomial Name	*Hammada Scoparia* Pomel.

Figure I.21. *Hammada Scoparia* Pomel.

IV.4.2. Synonyms

Hammada salicornia (Moq.) Iijin, *Hammada elegans* (Bunge) Botsch., *Haloxylon scoparium* Pomel., *Haloxylon articulatum subsp. Scoparium* (Pomel) Batt., *Haloxylon salicornicum* (Moq.) Bunge ex Boiss., *Arthrophytum scoparium* (Pomel) Il'jin., *Salsola articulata* Cav.

IV.4.3. Vernacular Names

Arabic: Remth lahmer, remth lakhder الرمث الأخضر، الرمث الأحمر

French: Saligne à balai

IV.4.4. Traditional uses

Hammada scoparia species were recorded to have folkloric uses. These species are very important in the medicinal practices of the Sahara people. Their aerial parts are boiled in tea to relieve rheumatism and joint problems. Washed and crushed, are applied topically to wounds caused by snake bites and scorpion stings, for which *Hammada scoparia* species are considered the best remedy.

In North Africa, they are used to treat eye disorders, to cure stomachache, scorpion bites, wounds infertility, and bone pain. Infusion and powder infusion of aerial part is sometimes used for their antidiabetic effects (Allaoui et al., 2014; Bourogaa et al., 2011; Tahar et al., 2017).

According to our recent investigations, the native people of Southwest Algeria (Adrar, Bechar, Naama, and Tindouf) are using *H. scoparia* to cure some infectious diseases, such as urinary and genital infections as well as to cure diseases related to skin problems (eczema, wounds and sepsis, itching, burns), rheumatism, diabetes, cancer, infertility problems, hair problems, Antitoxin, Stomach ache, pregnancy disorders, and poison (snake, scorpion, and insect) (Allaoui et al., 2014; Fatehi et al., 2017).

IV.4.5. Pharmaceutical Interests

H. scoparia were found to have antidiabetic and anticoagulant activity in previous studies (Tahar et al., 2017). Whereas the aqueous extracts have been showing an anticancer, antiplasmodial, and larvicidal activity (Allaoui et al., 2014). Furthermore, the extracts of *H. scoparia* species as well as their volatile oils were also studied and shown to exhibit antimicrobial activity especially against *Bacillus subtilis* and *Staphylococcus aureus*.

Recently, *H. scoparia* is reported to be used for hepatobiliary and eye disorders, as an anti-inflammatory, molluscicidal, antioxidant, and antiseptic agent (Allaoui et al., 2014; Bourogaa et al., 2011; Fatehi et al., 2017; Mezghani-Jarraya et al., 2009; Minocheherhomji, 2016; Ouled Belgacem and Louhaichi, 2013; Saidi et al., 2015; Taïr et al., 2016).

IV.4.6. Phytochemical Constituents

Several natural compounds were isolated from *H. scoparia* according to the latest research such as; Aliphatic quaternary alkaloids (Betaine chloride), Pyridine alkaloids (Piperidine, Anabasine, Aldotripiperideine, Haloxine, Halosaline, Nicotine), Indole alkaloids (Tryptamine), Isoquinoline alkaloids (N-methylisosalsoline, Carnegine, Isosalsoline, Salsolidine), Isoquinolone alkaloids (N-methylcorydaldine), and Phenylethylamine alkaloids (Oxedrine, Tyramine, N-methyltyramine) (Choudhary et al., 2006; Jarraya et al., 2008; Li et al., 2010; Mezghani-Jarraya et al., 2009). *Hammada scoparia* from Algeria also has been reported to contain specific alkaloids, flavonoids, and coumarins (Benkrief et al., 1990; Saidi et al., 2015).

IV.5. *Periploca laevigata* Ait.

Periploca laevigata (Asclepiadaceae), locally known as "Lhallab", is an erect small tree up to 3 m. high or a bushy branched shrub when nibbled by animals. The branches are interwoven; the foliage evergreen. The leaves are subsessile, with an entire, narrowly lanceolate limb. The flowers are grouped in little axillary cymes, with few flowers; the corolla is wheeled and has purple-brown lobes edged with a greenish-yellow, alternate, with 5 purple filaments hooked inwards. The fruit is dry, formed of two smooth divaricated follicles containing a number of small seeds (Heneidak and Naidoo, 2015).

P. laevigata is native to the Mediterranean region (southern Spain, Sicily, Malta, Crete, Lebanon, and Syria) and widely distributed in North African Sahara from Morocco to Egypt since it is found wild in the low and middle hills, descends southwards to the northern and central Sahara. In Algeria, it is predominantly found in the south of the country, especially in the Bechar region and Hagar (Ben Mimoun and Nouira, 2015; Faouzi et al., 2015; Fennane and Rejdali, 2016; Mezhoud et al., 2016; Stambouli-Meziane and Bouazza, 2014).

IV.5.1. Taxonomic Classification

Kingdom	**Plantae**
Division	Magnoliophyta
Class	Magnoliopsida
Order	Getianales
Family	Asclepiadaceae
Subfamily	periplocoideae
Genus	*Periploca*
Species	*P. laevigata* Ait.
Binomial Name	*Periploca laevigata* Ait.

Figure I.22. *Periploca laevigata* Ait.

IV.5.2. Synonyms

Periploca angustifolia Labill., *Periploca laevigata* var. *angustifolia* (Labill.) Fiori, *Periploca laevigata f. angustifolia* (Labill.) Ross, *Periploca laevigata* subsp. *angustifolia* (Labill.) Markgr., *Periploca laevigata* auct. Non Ait,

IV.5.3. Vernacular Names

Arabic: Lhallab الحلاب

French: Periploque

English: Cornical, cornicobra

IV.5.4. Traditional Uses

P. laevigata is reputed to possess medicinal properties, it is used to treat various diseases such as Rheumatism, Hemorrhoids, Gastric ulcer, and diabetes. In Algerian Sahara, it is used for the treatment of boils and buttons. whereas in Tunisia, it is taken as a tea and used as herbal medicine for the treatment of headaches and diabetes (Hammiche and Maiza, 2006; Mezhoud et al., 2016).

IV.5.5. Pharmaceutical Interests

The most studied *Periploca* species were reported to have various biological activities, such as antiproliferative, antitumor, and hypotensive effects. Previous studies, dealing with the significant antibacterial, antifungal, antioxidant and radical-scavenging activities of different solvent extracts as well as the essential oil of *P. laevigata*, have been also reported (Hajji et al., 2010; Hichri et al., 2003; Mohamed et al., 2009).

IV.5.6. Phytochemical Constituents

Previous studies of this species led to the isolation and identification of α- and β-amyrin, lupeol, β-sitosterol, and periplocadiol from the roots. However, the oleanolic acid, masilinic acid, 12α-hydroxy-δ-lactone of oleanolic acid, arjunolic acid, Asiatic acid, β-D-glucopyranose, and α-D-glucopyranose have been isolated from the fruit barks.

An additional phytochemical study led to the isolation and identification of lupeol arachidate, procrims A and B, and laevigatins I and II together with lupeol and lupeol acetate (Ben nejma et al., 2017; Hichri et al., 2003). Moreover, four known flavonoid glycosides named as kaempferol 3-O-β-arabinopyranoside, quercetin 3-O-β-glucopyranoside**,** quercetin 3-O-β- arabinopyranoside, and quercetin 3-O-rutinoside from *P. laevigata* growing in Algerian Sahara (Mezhoud et al., 2016).

IV.6. *Rhus tripartita* R. Sch.

Rhus tripartita (Anacardiaceae), locally known as "Jdari", has pseudo-thorns, a three-part leaf, and is usually encountered as a scrubby tree (0.5-2.0 meters tall). It is dioecious, flowering, and fruiting in winter. Desert populations are deciduous. Propagation is primarily through rhizoids and the trees live on the rocky slopes of canyons rather than in the canyon floor or on the desert plateau (Baum, 1991; Furth et al., 1983; Zouaoui et al., 2014).

R. tripartita grows in Mediterranean countries and the Middle East: Morocco, Algeria, Tunisia, Sicily, Libya, Egypt, North Sudan, Palestine, Jordon, and Lebanon (Baum, 1991; El-Ghanim et al., 2010; El-Salam and Mohammed, 2015; Hegazy et al., 2011; Ighbareyeh et al., 2014; Yahyaoui et al., 2015; Zouaoui et al., 2014).

IV.6.1. Taxonomic Classification

Kingdom	**Plantae**
Division	Magnoliophyta
Class	Eudicots
Subclass	Rosidae
Order	Sapindales
Family	Anacardiaceae
Genus	*Rhus*
Species	*R. tripartita* R. Sch.
Binomial Name	*Rhus tripartita* R. Sch.

Figure I.23. *Rhus tripartita* R. Sch.

IV.6.2. Synonyms

Rhus tripartitum (Ucria) D.C., *Rhus oxyacanthoides* Dum. Cours., *Rhus oxyacantha* Shousb. Ex. Cav.

IV.6.3. Vernacular Names

Arabic: Jdari, Tizgha جداري، تيزغا

French: Sumac

English: Sumac

IV.6.4. Traditional Uses

R. tripartita and other Rhus species are widely used in food and modern and traditional medicine. They have been used for the treatment of gastric ulcer, chronic diarrhea, colitis, urinary infections, inflammatory diseases, diabetes, dysentery, hemoptysis, conjunctivitis, animal bites and poisons, hemorrhoids, sexual disease, fever, pain, and various cancers (Alzweiri et al., 2011; Benkhnigue et al., 2016; El-Mokasabi, 2014; Ghourri et al., 2014; Miled et al., 2017; Qasem, 2015). *R. tripartita* fruits are also consumed fresh, soaked in sour milk, or added to drinking water to offer an acceptable taste (El-Salam and Mohammed, 2015).

IV.6.5. Pharmaceutical Interests

Rhus species are known for their therapeutic virtue and their extracts showed numerous important properties including antioxidant, antimicrobial, antiviral, anti-inflammatory, antiulcerogenic, antimalarial, antitumor, and hypoglycemic and anticonvulsant activities. Recent studies showed that *R. tripartita* root extracts also possess antioxidant and anti-inflammatory activities and were found to be active against lung and colon carcinoma cell lines (Abbassi and Hani, 2012; El-Salam and Mohammed, 2015; Gargoubi et al., 2015; Itidel et al., 2013; Miled et al., 2017).

IV.6.6. Phytochemical Constituents

Rhus species are among the plants which present high contents in polyphenols, phytochemical investigation of the alcoholic extract of *R. tripartita* resulted in the isolation of six compounds, gallocatechin, quercetin, myricetin, Kampferol-3-O-α-L-rhamnopyranoside, Kampferol-7-O-α-L-rhamnopyranoside, β-sitosteryl-3-O-β-glucopyranoside (El-Salam and Mohammed, 2015; Gargoubi et al., 2015; Itidel et al., 2013). *Rhus tripartita* extracts were also reported to contain interesting phenolics such as biflavonoids, isobiflavonoids, catechin, epicatechin-3-O-gallate, proanthocyanidin oligomers and polymers, polysaccharides, and condensed tannins (Abbassi and Hani, 2012; El-Salam and Mohammed, 2015; Miled et al., 2017).

IV.7. *Tamarix gallica* L.

Tamarix gallica (Tamaricaceae), locally known as “Fersig”, was first described for botanical classification by the Taxonomist Carothes Linnaceus in 1753 but had already been in cultivation since 1596 (Naveed et al., 2015). is a tree, often shrubby, up to 8 m height, with brackish-brown to deep purple bark; the stem diameter can reach up to 25 cm and the crown has an irregular shape. it has fragile, woody branchlets that drop off in autumn along with the small, scale-like leaves that cover them. The leaf shape is an adaption over time to exceedingly dry conditions the pink flowers are tiny, hermaphroditic, and are borne on narrow, feather-like spikes (Drabu et al., 2012; Naveed et al., 2015; Pandey et al., 2010; Rudberg, 2015).

T. gallica is widespread in the Mediterranean basin, it is usually found in Portugal, Spain, France, Italy, and North Africa. This species is very commonly distributed in coastal areas, salt marshes, on the riverbanks, and saline soils. It is very tolerant of salinity and drought. However, it also grows in exceedingly wet places (Fornasari, 2004; McAtee, 1914; Naveed et al., 2015; Rampim et al., 2014; Urfi et al., 2016).

IV.7.1. Taxonomic Classification

Kingdom	**Plantae**
Division	Magnoliophyta
Class	Magnoliopsida
Order	Violales
Family	Tamaricaceae
Genus	*Tamarix*
Species	*T. gallica* L.
Binomial Name	*Tamarix gallica* L.

Figure I.24. *Tamarix gallica* L.

IV.7.2. Synonyms

Tamarix anglica Webb, *Tamarix algeriensis* Hort., *Tamarix brachylepis* Sennen, *Tamarix madritensis* Pau & Villar.

IV.7.3. Vernacular Names

Arabic: fersig, Tarfa فرسيق، طرفة

English: French tamarisk, salt cedar

French: tamaris de France

IV.7.4. Traditional Uses

T. Gallica is employed in traditional medicines as astringent, apecitif, atimulus of perspiration, and diuretic. It is used also as a laxative, expectorant, anthelmintic, antidiarrheal, prophylactic, hepatoprotective, and for leucoderma, eye diseases, malaria, diarrhea, gingivitis, and rheumatism (Drabu et al., 2012; Karker et al., 2016; Ksouri et al., 2009; Urfi et al., 2016).

IV.7.5. Pharmaceutical Interests

Many pharmacological studies reported that *T. gallica* may be used as antimalarial, laxative, expectorant, antidiarrheal, anthelmintic, anti-hemorrhoid, astringent, an inhibitor of nephrolithiasis, diuretic, hepatoprotective, antioxidant, antihyperlipidemic, antinociceptive, antidiarrheal, anticancer, antimicrobial, liver carcinogenesis. It possesses also an anti-inflammatory and analgesic effect. Moreover, *Tamarix Gallica* has found in many commercial medicines like Liv 52, Digyton, geriforte Aqua vet, Liv 52 vet, Liv 52 DS (Bensatal and Ouahrani, 2008; Drabu et al., 2012; Karker et al., 2016; Ksouri et al., 2009; Naveed et al., 2015; Sehrawat and Sultana, 2006; Urfi et al., 2016).

IV.7.6. Phytochemical Constituents

T. gallica is found to be rich in polyphenolic compounds such as flavonoids, sulfur-containing flavonoids, phenolic acids, and coumarins. Its principal constituent is an alkaloid, tamarixin, along with traces of its aglocone, tamarixetin. The plant also contains a high level of tannin (ellagic and gallic) and quercetol (methyllic esther). It also constituted antioxidants like carotenoids and essential oils (Drabu et al., 2012; Ksouri et al., 2009; Lefahal et al., 2010; Pandey et al., 2010; Urfi et al., 2016).

IV.8. *Traganum nudatum* Del.

Traganum nudatum (Chenopodiaceae), locally known as “Domrane”, is a small shrub, not exceeding 50 cm., with intricate grey-whitish stems. The leaves are alternate, fleshy, ovoid, with a very small yellowish curved spine at the top, bright green, 2-4 mm. The small solitary yellow flowers are located at the base of the leaves and surrounded by white woolly hairs. The perianth has 5 cream tepals. The fruit is a small achene surrounded by the perianth when the fruit is ripe (Daoud and Al-Rawi, 1985; Mandaville, 1990).

T. nudatum is a native halophytic shrub in arid zones of the Mediterranean basin and the Middle East. Extreme conditions of high temperatures, salinity, and aridity can be tolerated by these species (Ahmed et al., 2015; Al-ghanem, 2011; Badawneh et al., 2017; Hadjoudj et al., 2015; Halis et al., 2012; Louhaichi et al., 2011; Smail-saadoun, 2005).

IV.8.1. Taxonomic Classification

Kingdom	**Plantae**
Division	Magnoliophyta
Class	Magnoliopsida
Order	Caryophyllales
Family	Chenopodiaceae
Subfamily	Salsoloideae
Genus	*Traganum*
Species	*T. nudatum* Del.
Binomial Name	*Traganum nudatum* Del.

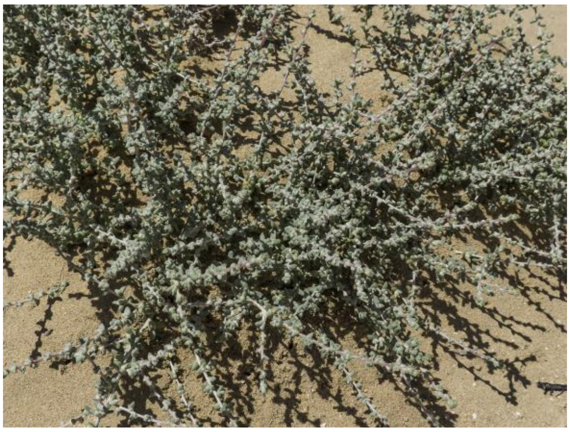


Figure I.25. *Traganum nudatum* Del.

IV.8.2. Synonyms

Traganum nudatum Delile, *Traganum acuminatum* Maire & Weiller, *Traganum nudatum* var. *acuminatum* (Maire & Weiller) Maire, *Traganum nudatum* var. *microphyllum* Maire

IV.8.3. Vernacular Names

Arabic: Demrane ضمران

French: Tragam Dénudé

IV.8.4. Traditional Uses

T. nudatum is widely used in folk medicine to cure some diseases such as diarrhea, wounds, rheumatism, and dermatosis (Allaoui et al., 2014; Badawneh et al., 2017; Borgi et al., 2011; DIDI et al., 2003; Qasem, 2015), Constipation (Bouaziz et al., 2009; Hammiche and Maiza, 2006), Intestinal disorders, aching bones, joints and muscular pains (Maiza et al., 2011)

IV.8.5. Pharmaceutical Interests

T. nudatum has been rarely subjected to pharmaceutical studies in spite of its wide use in folk medicine. The few conducted research reported that it has significant antibacterial and antioxidant activities (Allaoui et al., 2014; Gherraf et al., 2011; Labed et al., 2010; Qasem, 2015). A recent study was designed to evaluate the efficacy of ethanolic extracts of *T. nudatum* in reversing the hyperglycaemia in alloxan induced diabetic rats, (Badawneh et al., 2017)

IV.8.6. Phytochemical Constituents

Phytochemical screening of *T. nudatum* extracts demonstrated the presence of Alkaloids, tannins, saponins, and flavonoids abundantly in this plant (Badawneh et al., 2017; Labed et al., 2010), but no data was found for the phytochemical constituents isolated from *T. nudatum.*

V. Conclusion

Plants are an important source for the discovery of new products of medicinal value for drug development and plants' secondary metabolites are unique sources for pharmaceuticals drugs, food additives, flavors, and other industrial values.

Healing with medicinal plants is as old as mankind itself. The connection between man and his search for drugs in nature dates from the far past, of which there is ample evidence from various sources: written documents, preserved monuments, and even original plant medicines.

A good number of abstracts and research articles published, so far, for evaluating the pharmacological activity of different secondary metabolites which have been extracted from various medicinal plants worldwide.

Of the medicinal plants encountered in the desert of southwest Algeria, nine of the most popular medicinal plant species frequently used in the local traditional medicine in the Bechar region namely *Andropogon nardus* L., *Andropogon schoenanthus* L., *Globularia alypum* L., two species of *Hammada scoparia* Pomel., *Periploca laevigata* Ait., *Rhus tripartita* R. Sch., *Tamarix gallica* L. and *Traganum nudatum* Del., are reviewed and subjected in this research for further studies.

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Chapter 2

Materials & Methods

I. INTRODUCTION

In ancient cultures, people developed their own herbal pharmacopeias based on information gained through experience, and in our today's scientific pharmacopeia much of the information on scientific medicine is derived from those herbal pharmacopeias (Tolera et al., 2017).

The knowledge and use of plants are an integral part of many cultures in Algeria, the extent of which has not yet been studied in depth (Djahafi et al., 2021). Therefore, the present work was undertaken with the aim to collect detailed information about the usage of spontaneous medicinal plants in human therapy in the Bechar region, and evaluate the phytochemical, antioxidant, and antimicrobial properties of nine ethno-therapeutically important medicinal plants, traditionally used for treating various ailments in Southwest Algeria.

II. ETHNOBOTANICAL STUDY

The knowledge of the use of medicinal plants and the procedures applied to their preparation is usually transmitted from generation to generation, but it is often in danger because transmission between older and younger generations is not always assured (Grujičić et al., 2020; Iqbal et al., 2018; Salmerón-Manzano et al., 2020). Consequently, it is essential to make the complete inventory of the medicinal component of the flora of any country for conservation and sustainable use (Addo-Fordjour et al., 2013; Saadi et al., 2013).

Algeria, with its large area and diversified climate, has a varied flora, which is a source of rich and abundant medical matter (Baziz et al., 2020; Hadjadj et al., 2015). The use of medicinal plants occupies an important place in traditional Algerian medicine and continues to be highly active, especially among local population. This knowledge is mainly resulted from the local cultural influences (Berber, Maghreb, and African) and originated from the medical heritage of Muslim civilization, transmitted from generation to generation (Baziz et al., 2020; Benaiche et al., 2019; Bouafia et al., 2021).

However, this knowledge has declined and is at risk of loss, essentially because recent economic development combined with the modernization of infrastructure leaded young people to move away from rural localities, thereby breaking the oral transmission of this ancestral knowledge from older generations (Baziz et al., 2020; Bouafia et al., 2021; Djahafi et al., 2021).

Although many studies have been carried out on the ethnomedicinal uses of plants described from different places in Algeria (Benaiche et al., 2019; Boudjelal et al., 2013; Chermat and Gharzouli, 2015; Hadjadj et al., 2015; Laid et al., 2014; Meddour et al., 2016; Ramdane et al., 2015; Rehamn and Sultana, 2015; Sarri et al., 2014, 2012), the composition of the Algerian Sahara vegetation carpet has been the subject only of few works, such as those of (Ozenda, 1977; Quézel, P., Santa, 1962; Quezel and Santa, 1963).

Like many regions in Algerian Sahara, the Bechar area abounds in an important ecological and floristic diversity. It is rich in natural and botanical resources and consecrated by the presence of a large number of endemic, rare, or threatened species.

Although several detailed studies relating to the diversity of local flora have been undertaken, it seems that very few studies concerning methods of traditional medicine preparation, parts used, and routes of applications of medicinal plants by local populations have been made.

In this context, we have conducted an ethnobotanical study in the Bechar region, this study consists of the design and analysis of a series of ethnobotanical surveys to identify the spontaneous plants used in traditional medicine by local population and to inform about their importance in the therapeutic uses practiced in the region.

II.1. Study Area

The current study was conducted out in the region of Bechar, Southwest Algeria (31°37' N latitude, 2°13' W longitude), which is located 1150 km away from Algiers, and covering an area of 161,400 km². It is limited to North by the Wilaya of Naama, to East by the Wilaya of Elbayedh, to South by the Wilayas of Adrar and Tindouf, and to West by the Kingdom of Morocco (Figure II.1).

The total population residing in the region is estimated at about 299,839 inhabitants, with a density of 1.8 inhabitants/km^2. This region’s population is mixed between African, Arabic, and Amazigh ethnicity.

The arid climate spreads to the region go through long periods of heat from May to September, where the temperature reaches sometimes 40°C to 45°C maximum and very low annual rainfall rate (16.9 mm).

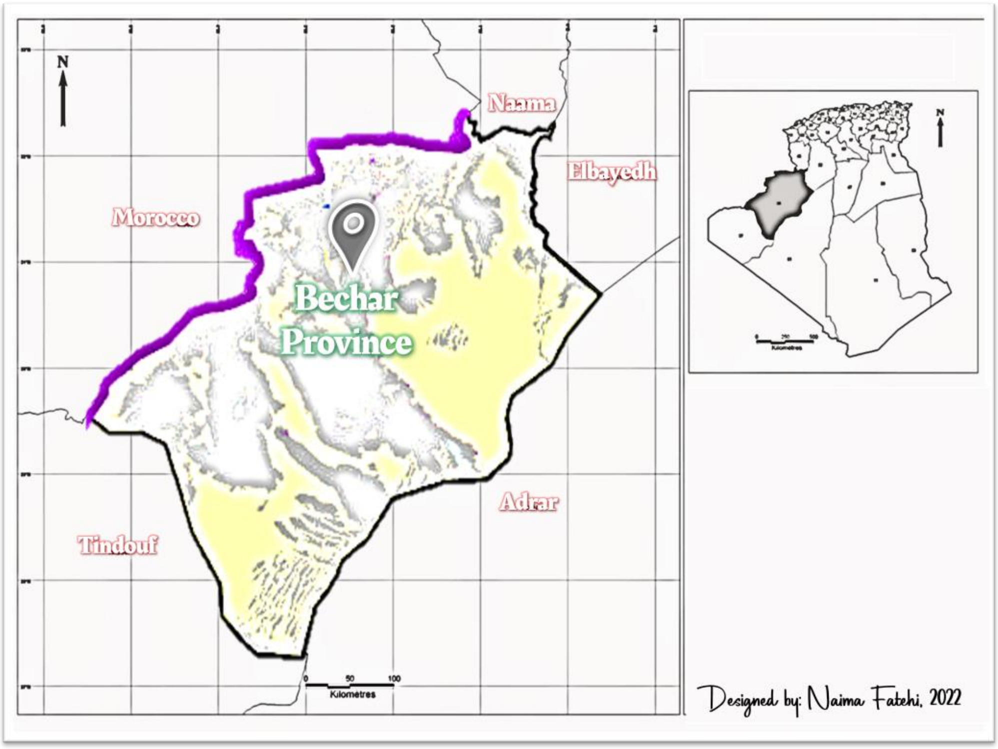

Figure II.1. Study Area (Bechar Province, Southwest Algeria)

II.2. Population, Sample, and Data Collection

The ethnobotanical data was collected between June 2013 and July 2015, based mainly on semi-structured questionnaires and open-ended conversations with more than 250 traditional healers, herbalists, herbal practitioners, and nomads in different localities of Bechar Province. The respondents were selected based on their reputation and ability to demonstrate good traditional herbal medicine knowledge.

Interviews and discussions were conducted in the Arabic language, the common local language in the study area. At each interview, the following data were gathered: Age and sex, vernacular name of the used plants, cultivated species or spontaneous, part of the plant being used, the therapeutic uses, mode of preparation, and administration. Since the knowledge is a natural wealth of the local people, they were assured that the data would be used only for academic purposes.

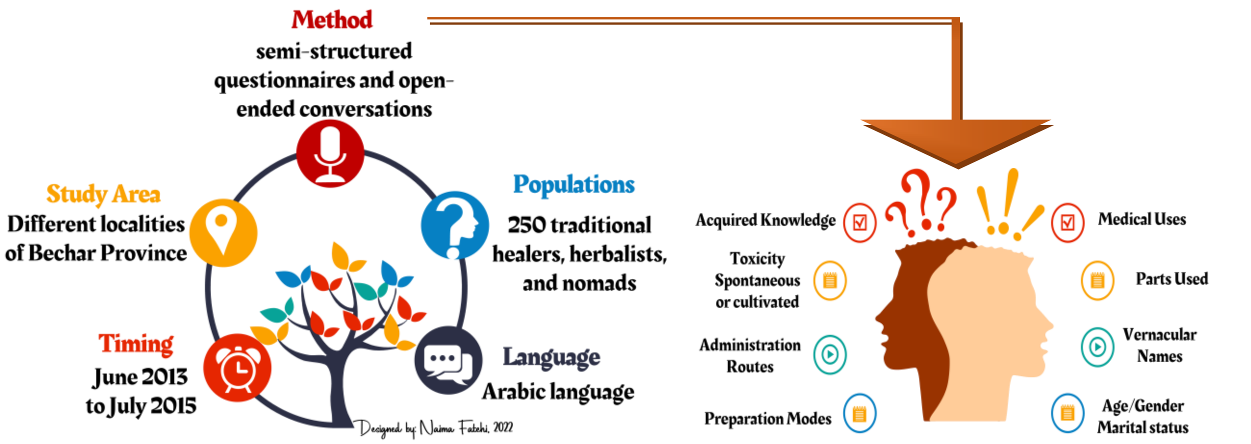

Figure II.2. Ethnobotanical Survey and Data Collection

Under the supervision of the traditional healers, plant specimens were collected by the first author to produce voucher specimens and deposit in the herbarium at the pedagogic laboratory of biology, TAHRI Med University of Bechar.

The collected plant samples were identified based on the "Flora and vegetation of Sahara" (Ozenda, 1983) and the Algerian flora of Quezel and Santa (1962-1963). Then updated according to the synonymic index of the North Africa flora (Dobignard and Chatelain, 2010), The Plant List: **www.theplantlist.org**, and The Global Biodiversity Information Facility: **www.gbif.org** accessed on 01 October 2018. The botanical families follow the Angiosperm Phylogeny Group (APG) IV system (Chase et al., 2016).

II.3. Quantitative Analysis of Ethnobotanical Data

In analyzing data collected through the interviews, some quantitative indices commonly adopted in ethnobotanical studies were used. Here in this study, three quantitative tools like Percentage of respondents who have knowledge (Friedman et al., 1986)**,** the Importance value (Byg and Balslev, 2001), and the Fidelity level index (Alexiades, 1996; Friedman et al., 1986) were employed to analyze the collected data.

The percentage of respondents who have knowledge (PRK) regarding the use of a species (frequency of citation) in the treatment of diseases was estimated using the formula: **PRK= Is/n x100**, where '**Is**' is the number of people interviewed citing species, and '**n**' is the total number of people interviewed.

The Importance Value (IVs) measures the proportion of informants who regard a species as most important and is calculated as follows: $\mathbf{IV_s = n_{is}/n}$, where '$\mathbf{n_{is}}$' is the number of people interviewed who consider the species most important, and '**n**' is the total number of people interviewed.

The Fidelity level index is the percentage of informants claiming the use of a plant species for the same major purpose. It is estimated as follows: $\mathbf{FL = I_p/I_u \times 100}$, where '$\mathbf{I_p}$' is the number of informants who indicate the use of a species for the same major ailment, and '$\mathbf{I_u}$' is the total number of informants who mentioned the plant for any other use.

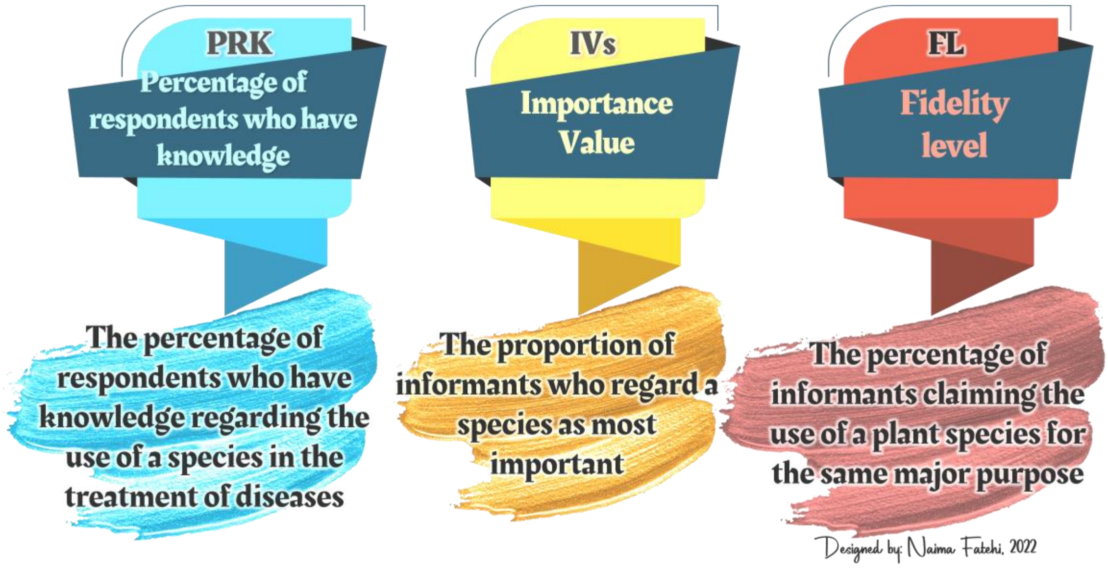

Figure II.3. Quantitative Analysis of The Ethnobotanical Data

III. Phytochemical Study

Knowledge of the chemical constituents of plants is desirable not only for the discovery of therapeutic agents but also because such information may be of great value in disclosing new sources of economic phytocompounds for the synthesis of complex chemical substances and for discovering the actual significance of folkloric remedies (Doss et al., 2017).

Today in this modern world, even though synthetic drugs are readily available and highly effective in curing various diseases, there are people who still prefer using traditional folk medicines because of their less harmful effects (Iqbal et al., 2015).

There is a wide diversity of compounds, especially secondary metabolites, found and isolated from plants and studies have shown that these compounds have anticancer, antibacterial, antitumor, antiviral and many other activities to a greater or lesser extent (Priestap, 1985; Cai et al., 2004; Miliauskas et al., 2004; Wiart, 2007).

This part focus on the assessment of phytochemical of the crude aqueous and hydromethanolic extracts of nine folkloric medicinal plants from the Bechar region namely: *A. nardus, A. schoenanthus, G. alypum*, two species of *H. scoparia* green & red, *P. laevigata, R. tripartita, T. gallica*, and *T. nudatum*. These plants are frequently used in local traditional medicine.

III.1. Sources and Collection of Plants Materials

The choice of plants is based on a survey of the ethnopharmacological population with knowledge of their use in traditional medicine. Nine plants were collected from March 2014 to March 2015, from different regions of Bechar province. After collection, the fresh plant samples were cut into pieces and ambient dried in shade, then grinded and stored until use.

III.2. Extraction Procedure

A total of 50 g of each plant material was exhaustively refluxed with distilled water and 80% water-methanol mixture separately for 3h. The extracts were filtered out, concentrated, and dried over a Rota-vapor. Then the yielded percentage was calculated.

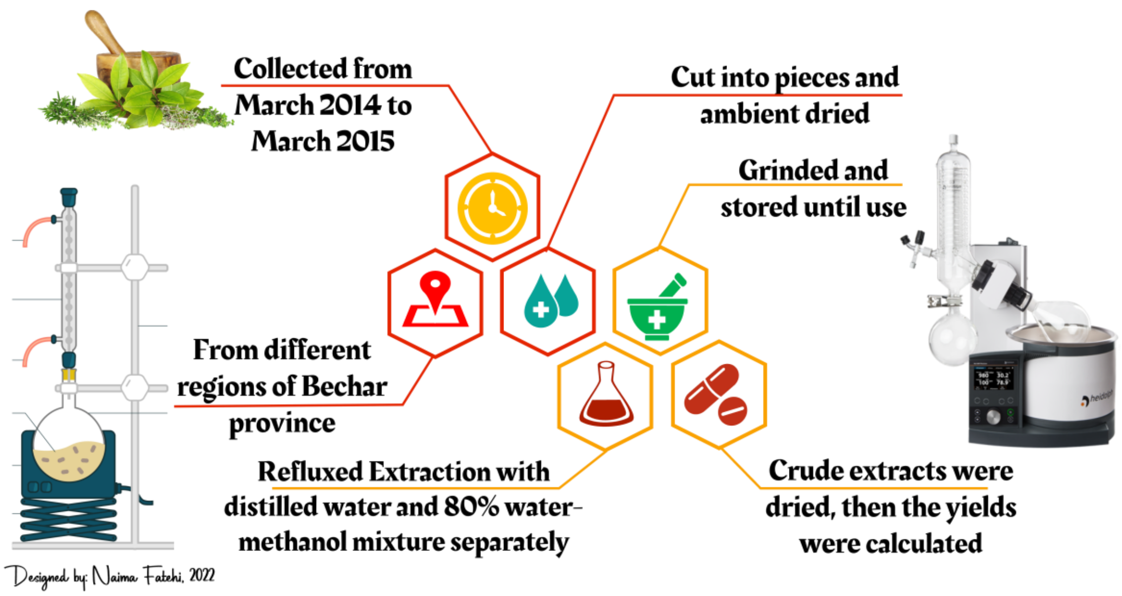

Figure II.4. Extraction Procedure

III.3. Phytochemical Screening

A qualitative phytochemical screening was carried out on the extracts of the nine selected plants to detect the presence or the absence of secondary metabolites (flavonoids, alkaloids, saponins, steroids, terpenoids, tannins, coumarins … etc.) using standard procedures (Harborne, 1973; Sofowora, 1993; Trease and Evans, 1989).

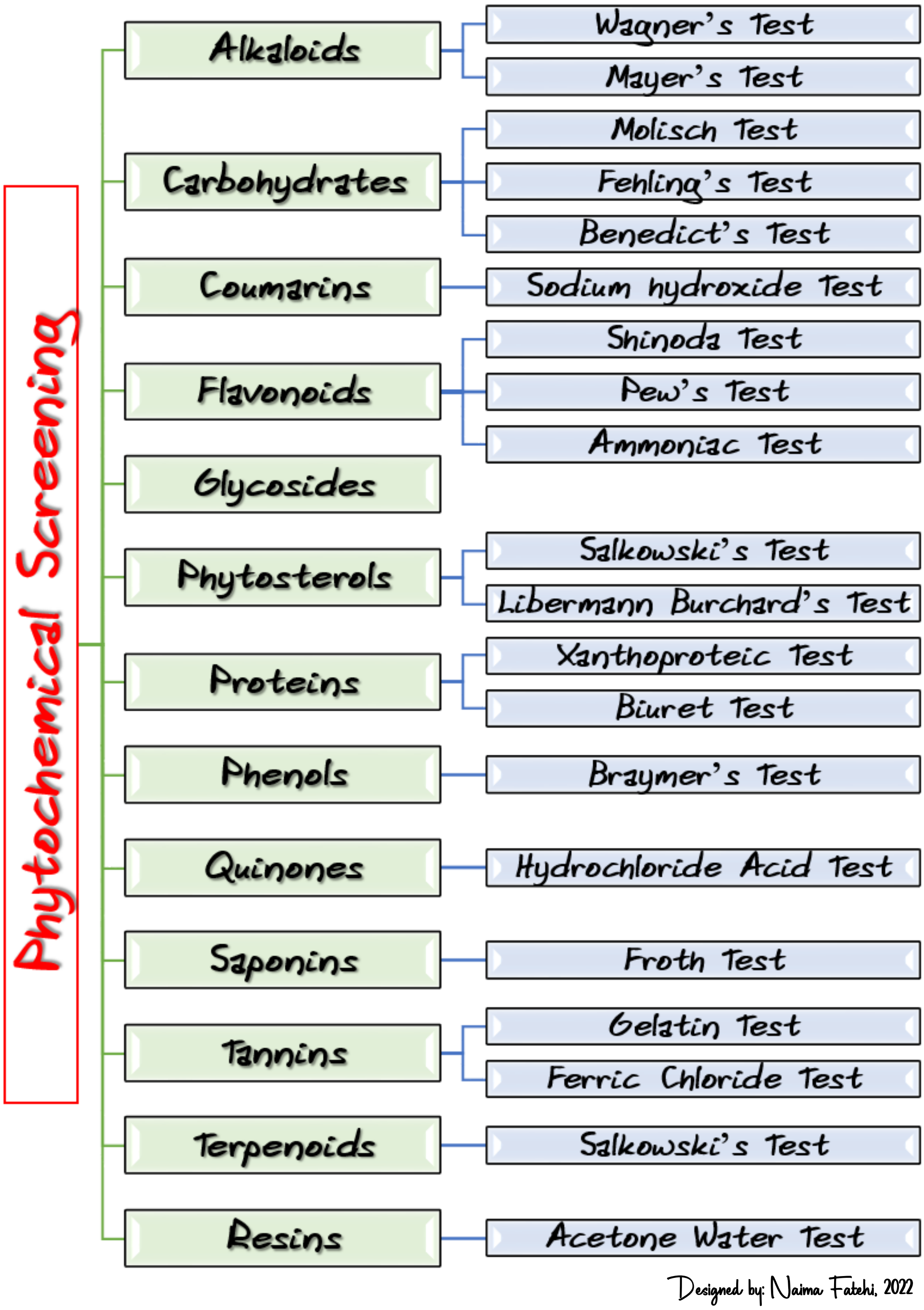

Figure II.5. Qualitative Phytochemical Screening Tests

Table II.1. Qualitative Phytochemical Screening Procedures

Phyto-constituents		Chemical test	Positive results
Alkaloids	**Mayer's Test**	Extracts were treated with 1% HCl on a water bath, then Mayer's reagent was added	Turbidity or yellow-colored precipitate formation
	Wagner's Test	Extracts were treated with 1% HCl on a water bath, then Wagner's reagent was added	
Carbohydrates	**Molisch Test**	Extracts were treated with drops of alcoholic alpha-naphthol and drops of conc. H_2SO_4	A purple to violet color ring appears at the junction
	Fehling's Test	Extracts were treated with Fehling A and Fehling B reagents, then boiled	Brick red colored precipitate
	Benedict's Test	Extracts were treated with Benedict's reagent, then heated in a water bath	Orange-red precipitate
Coumarins	**Sodium Hydroxide Test**	Extracts were treated with 10% NaOH	Yellow color
Flavonoids	**Lead Acetate Test**	Extracts were treated with drops of 10% lead acetate solution	Yellow precipitate
	Shinoda Test	Extracts were treated with a bit of magnesium and some drops of conc. HCl, then heated	Red or orange color
	Ammoniac Test	Extracts were treated with 10 % NH_4OH	Yellow fluorescence
	Pew's Test	Extracts were treated with zinc dust and conc. HCl	Red color
Anthocyanins	**Sodium Hydroxide Test**	Extracts were treated with 2N NaOH and heated for 5 min at 100^{o}C.	Bluish-green color
Betacyanins			Yellow color
Cyanidin aglycones	**Willstätter Cyanidin Test**	Extracts were treated with conc. HCl and pieces of magnesium turnings	Purple colored solution
Leucoantho-cyanins	**Isoamyl Alcohol Test**	Extracts were treated with Isoamyl alcohol	The upper layer appears red

Phyto-constituents		Chemical Test	Positive Results
Glycosides	**Modified Borntrager's Test**	Extracts were treated with $FeCl_3$ solution, then immersed in boiling water for 5 minutes. The mixture was cooled and extracted with equal volumes of benzene. The benzene layer was treated with NH_4OH solution.	Rose-pink color
Phytosterols	**Salkowski's Test**	Extracts were treated with chloroform and filtered. Some drops of conc. H_2SO_4 was added to the filtrates, then shaken and allowed to stand.	Golden yellow color
	Libermann Burchard's Test	Extracts were treated with chloroform and filtered. Acetic anhydride was added to the filtrates, boiled and cooled, then conc. H_2SO_4 was added	Brown ring at the junction
Proteins	**Xanthoproteic Test**	Extracts were treated with drops of conc. HNO_3	Yellow color
	Biuret Test	Extracts were treated with 10% NaOH and heated, then drops of 0.7% $CuSO_4$ solution was added	Purplish Violet Color
Phenols	**Braymer's Test**	Extracts were treated with drops of 5% $FeCl_3$ solution	Greenish Blue, Violet, or Bluish Black Color
Quinones	**Hydrochloride Acid Test**	Extracts were treated with conc. HCl	Yellow Precipitation or Coloration
Saponins	**Froth Test**	Extracts were mixed with distilled water then agitated in a graduated cylinder for 15 min.	Foam Formation
Tannins	**Gelatin Test**	Extracts were treated with drops of 1 % gelatin solution containing NaCl	White Precipitate
	Ferric Chloride Test	Extracts were treated with drops of 1% $FeCl_3$	Green or Blue Color
Terpenoids	**Salkowski's Test**	Extracts were treated with chloroform and conc. H_2SO_4	Reddish Brown Coloration
Resins	**Acetone-Water Test**	Extracts were treated with acetone and water then shaken.	Turbidity

III.4. Determination of Total Phenolic Contents (TPC)

Total phenolic contents were determined by the Folin-Ciocalteu colorimetric method using gallic acid as standard (Singleton et al., 1999). Briefly, 0.2 mL of each extract were added to 0.8 mL of a solution of Na_2CO_3 (75 mg/mL distilled water), after stirring, 1 mL of Folin-Ciocalteu solution (1/10 dilution) is added to the overall, after 2h of incubation in the dark at room temperature, the absorbance at 765 nm is measured by UV-visible spectrophotometer. The concentration of the total phenolics was calculated as mg of gallic acid equivalent by using an equation obtained from the gallic acid calibration curve.

III.5. Determination of Total Flavonoid Contents (TFC)

Total flavonoid contents were performed according to the colorimetric assay using quercetin as standard (Kim et al., 2003). Briefly, 0,25 mL of each extract was added to 1,25 mL of ddH_2O separately. Subsequently, 75 µL of 5% $NaNO_2$ was added to the mixture. After the mixture was allowed to stand for 5 min, 150 µL of 10% $AlCl_3$ was added. The mixture was incubated at ambient temperature (25°C) for an additional 5 min. Following that 0.5 mL of 1 M NaOH was then added to the mixture. The mixture was immediately diluted by the addition of 275 µL of ddH_2O and the absorbance of the mixture was measured at 510 nm. The concentration of the total flavonoids was calculated as mg of quercetin equivalent by using an equation obtained from the quercetin calibration curve.

III.6. Determination of Total Polysaccharide Contents (TPSC)

The total polysaccharide contents were determined by the Phenol-Sulfuric acid method using glucose as standard (Dubois et al., 1956). Briefly, 2 mL of each extract were pipetted into a test tube, and 1 mL of 5% phenol solutions were added. Then 5 mL of concentrated sulfuric acids were added rapidly. The tubes were shaken and placed in a water bath at 30º C before the reading's procedure was taken. The absorbance of the characteristic yellow-orange color was measured at 490 nm. The concentration of the total polysaccharide was calculated as mg of glucose equivalent by using an equation obtained from the glucose calibration curve.

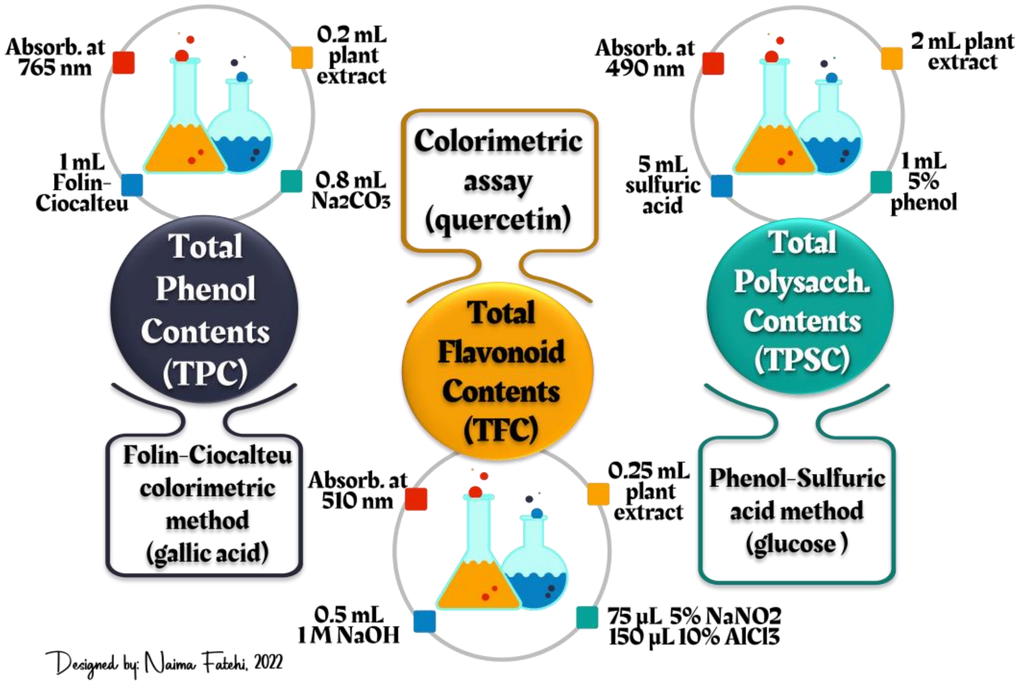

Figure II.6. Qualitative Phytochemical Screening

III.7. High-Performance Liquid Chromatography Analysis

The presence of phenolic compounds in two hydromethanolic extracts (*P. laevigata* and *R. tripartita*) was studied by reversed-phase HPLC analysis using binary gradient elution. The phenolic compounds analysis was carried out using an Agilent Technologies 1100 series liquid chromatography coupled with a UV–vis detector. The separation was carried out on a 250mm × 8mm, particle size 5µm Eurospher-100 C18 reversed-phase column at ambient temperature. The mobile phase consisted of Methanol (solvent A) and water with 0.2% sulphuric acid (solvent B). The flow rate was kept at 1 ml/min. The injection volume was 20 µL, and peaks were monitored at 260 nm. Samples were filtered through a 0.45µm membrane filter before injection.

Commercially phenolic standards, quercetin, catechin, caffeic acid, ferulic acid, naringenin, and p-coumaric acid, were separately dissolved in methanol (0.5 mg/ml) then analyzed by HPLC, as external standards, using the same conditions cited earlier.

In this study, the Response Factor (RF) is used for the determination of the concentration of unknown samples, RF can be determined for each standard as follows: **RF = Stand. Area / Stand. Conc.** Therefore, the sample concentration can be calculated using the following formula: **Sample Conc. = Sample Area / RF** (Chakravarthy et al., 2011; Lee, 2004)**.**

IV. *In Vitro* Antioxidant Activity

The antioxidant potential of plants extracts was highlighted using three methods: DPPH, FRAP, and TAC. Ascorbic acid, gallic acid, and quercetin were used as the reference antioxidants.

IV.1. Total Antioxidant Capacity (TAC)

The total antioxidant capacity of the plant extracts was measured by the method of (Prieto et al., 1999). Briefly, the extracts were prepared in their respective solvents (1mg/mL) and mixed with 1mL of the reagent solution (0.6M sulfuric acid, 28mM sodium phosphate, 4mM ammonium molybdate mixture). The tubes were incubated for 90 min at 95ºC. The mixture was cooled to room temperature and the absorbance was read at 695 nm against a blank sample. Total antioxidant capacity is expressed as mg per gram of a plant extract, in ascorbic acid equivalent.

IV.2. Ferric Reducing Antioxidant Power (FRAP)

Ferric reducing antioxidant power of the plant extracts was determined by the method described by (Yildirim et al., 2001). Briefly, the extracts were mixed with 2.5 mL of phosphate buffer (0.2M, pH 6.6) and 2.5 mL of 1% potassium ferricyanide and then incubated at 50°C for 30 min. Afterward, 2.5 mL of 10% trichloroacetic acid was added to the mixture, which was then centrifuged at 3000 rpm for 10 min. Finally, 2.5 mL of upper layer solution was mixed with 2.5 mL distilled water and 0.5 mL of 0.1% $FeCl_3$, and the absorbance was measured at 700 nm. Results were expressed as milligrams of ascorbic acid equivalent per gram of extract.

IV.3. DPPH Radical Scavenging Assay

IV.3.1. Qualitative DPPH Radical Scavenging Assay

The antioxidant activity of the extracts was determined qualitatively by TLC assay and Microtiter plate assay (Hsiao et al., 1996; Purushothaman et al., 2013; Sakthi and Muthuswamy, 2013).

For the TLC assay, an aliquot (3 µL) of each extract and standard (Quercetin and Ascorbic acid) was carefully loaded onto a silica gel plate and allowed to dry. After 5 minutes, the TLC plate was sprayed with 0.2% DPPH in methanol. Discoloration of DPPH indicates the scavenging potential of the compound tested.

For the microtiter plate assay, an aliquot (50 µL) of each extract and standard was taken in the microtiter plate separately. Methanolic DPPH (100 µL of 0.1%) was added over the samples and incubated for 30 minutes in dark conditions. The samples were then observed for discoloration from purple to yellow and pale pink were considered as strong and weak positive respectively.

IV.3.2. Quantitative DPPH Radical Scavenging Assay

Radical scavenging activity of extracts was also determined quantitatively using the method of (Samarth et al., 2008) using ascorbic acid, acid gallic, and quercetin as standards. Briefly, to 0.1 mL of various concentrations of each extract (0.01-0.5 mg/mL), 1.9 mL of DPPH solution (0.004%) was added. An equal amount of methanol and DPPH served as control. The mixture was shaken vigorously and was left to stand in dark for 30 min. The absorbance of the resulting solution was measured at 517nm.

The percentage scavenging activity of each extract on DPPH radical was calculated using the following formula: **Scavenging activity (%) = {1- (Absorbance of the sample) / (Absorbance of the control)} ×100.** DPPH radical scavenging activities of the extracts were expressed as IC_{50} values. IC_{50}, the effective concentration of the extract required for 50% scavenging of DPPH radical, was calculated from the graph of scavenging activity plotted against sample concentration.

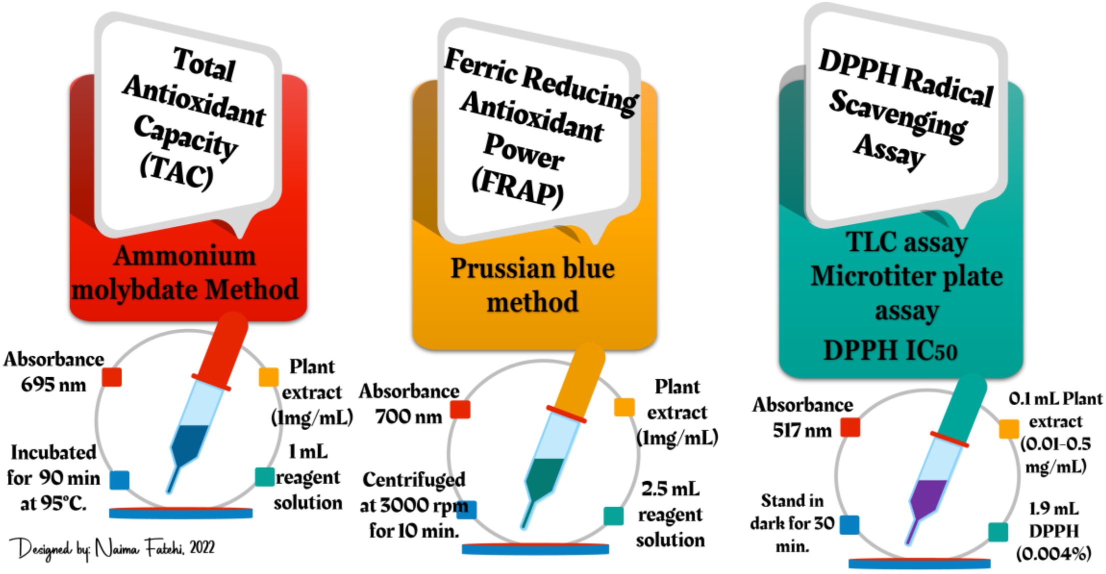

Figure II.7. *In Vitro* Antioxidant Activity

V. *IN VITRO* ANTIBACTERIAL ACTIVITY

Today there is an imperative necessity to find out new antibacterial compounds with various chemical structures and new mechanisms of action for new and re-emerging contagious syndromes (El-bashiti et al., 2017; Pooja et al., 2016; Sharifah Raina and Hassan, 2016).

Consequently, researchers are increasingly turning their attention to folk medicine, looking for new leads to develop better drugs that are effective against bacterial infections extracts of screened medicinal plants possess a broad spectrum of activity against a panel of bacteria responsible for the most common bacterial diseases (Dathar and Afrojahan, 2017). These promissory extracts open the possibility of finding new clinically effective antibacterial compounds (Kage et al., 2009).

Therefore, the antibacterial screening of aqueous and hydromethanolic extracts of the investigated medicinal plants was conducted using the disc diffusion method agar and antibiotics susceptibility.

V.1. Bacterial Strains

The antibacterial potency of each plant extract was evaluated against ten bacterial strains, seven reference strains, *Bacillus cereus* (ATCC 11778), *Enterococcus faecalis* (ATCC 29212), *Staphylococcus aureus* (ATCC 25922), *Escherichia coli* (ATTC 25923), *Klebsiella pneumonia*, *Pseudomonas aeruginosa* (ATCC 27853), *Salmonella typhi* (ATCC 25922), provided from Pasteur institute, Algiers, Algeria, and three clinically isolated strains, *Escherichia coli* (Urinary Tract Infection (UTI)), *Escherichia coli* (Vaginal Infection (VI)) and *Staphylococcus aureus* (*Skin Infection* (SI)), provided from Microbiology Laboratory, TOURABI Boudjamaa Hospital, Bechar, Algeria.

V.1.1. Isolation and Identification of the Infectious Strains

For the isolation of the three clinical isolates used in this study, samples were collected randomly from the infectious patients from TOURABI Boudjamaa Hospital, Bechar. The samples collected were then plated onto Mac Conkey's agar, Mannitol salt agar, and Nutrient Agar plates for bacterial isolation using a sterilized loop. The plates were then incubated at 37°C for 24 hrs. The plates were observed for bacterial growth after 24 hrs. In some plates, there were mixed cultures of organisms. These plates were subsequently subcultured to isolate the pure strain. Morphological identification was done by using the Gram staining technique. Further, characterization of organisms was carried out by various biochemical tests, and the results were tabulated (Frerichs and Millar, 1993; Mahon and Manuselis, 2006).

V.1.2. Inoculums Preparation

Each bacterial strain was subcultured overnight at 35 °C in Mueller-Hilton agar slants. The bacterial growth was harvested using 5 mL of sterile saline water. The concentration of the suspensions was adjusted to 0.5 Mc Farland standard to reach an optical density of 0.08-0.10 at 625 nm by adding sterile distilled water (McFarland, 1907), this gives a bacterial suspension containing $1.5x10^8$ CFU/mL (Hindler and Jorgensen, 2000).

V.2. Antibiotic Sensitivity Assay

The antibiotic sensitivity against the ten bacterial strains was determined using the disc diffusion method cited earlier. Seven antibiotics were used in this study including Ampicillin (10 µg), Ofloxacin (5 µg), Fosfomycine (200 µg), Cefoxitin (30 µg), Gentamycin (10 µg), Oxacillin (1 µg) and Tetracycline (30 µg).

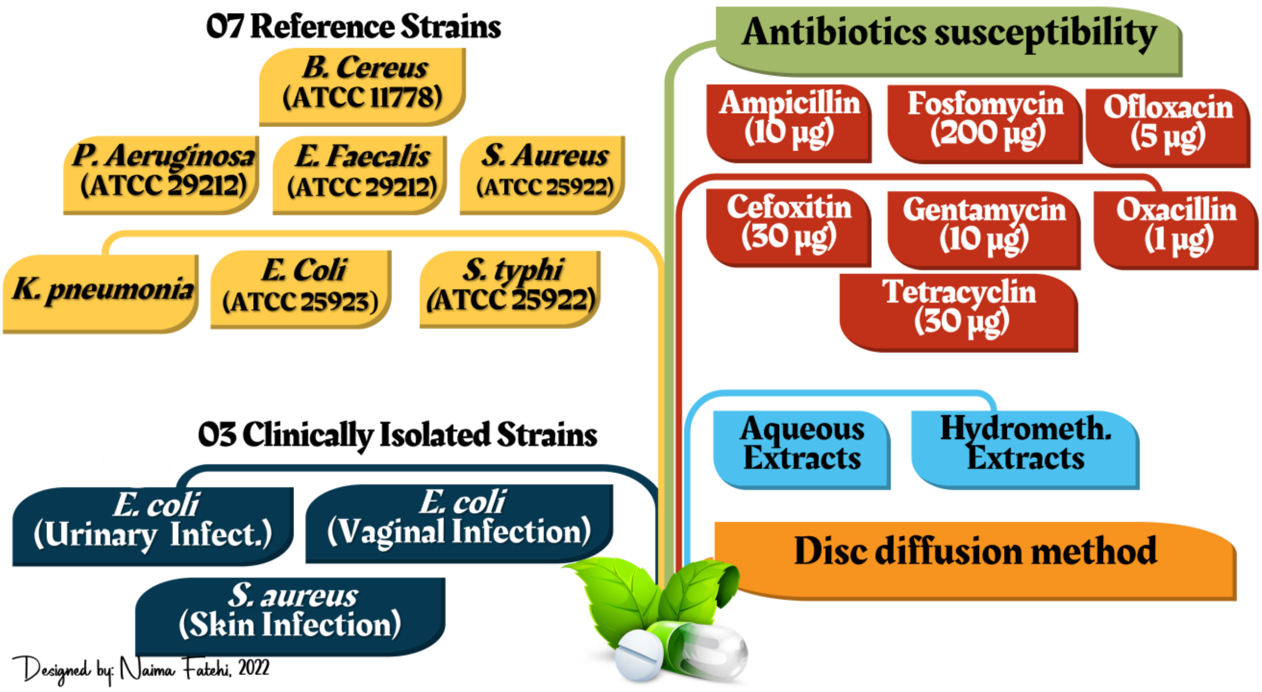

Figure II.8. Antibacterial and Antibiotic Sensitivity

V.3. Antibacterial Activity of Plant Extracts

The disk diffusion method is used to evaluate the antibacterial activity of each plant material. The plant extract residues (100 mg) were re-dissolved in 1 mL of sterilized Dimethyl sulfoxide (DMSO 5%), then loaded over sterile filter paper discs (6 mm in diameter). 10 mL of Mueller-Hilton agar medium was poured into sterile Petri followed with the seeded medium previously inoculated with bacterial suspension. Sterile filter paper discs loaded with 40 µl of each plant extract separately were placed on the top of Mueller-Hilton agar plates. Sterile paper discs containing Dimethyl sulfoxide (DMSO 5%) alone was served as control. The plates were incubated at 37 °C for 24 h.

The presence of inhibition zones was measured by Vernier caliper, recorded, and considered as an indication for antibacterial activity. For each test solution, three replicates were maintained (Bauer et al., 1966; Carson and Riley, 1995; Casella et al., 2013; Gupta et al., 2014). Then, the proportion index (PI) was calculated as:

PI = NP_E/T_N, where **'NP_E'** is the Number of positive results obtained for extract, and **'T_N'** is the total number of tests carried out for each extract (Borgio et al., 2007; Singh et al., 2002).

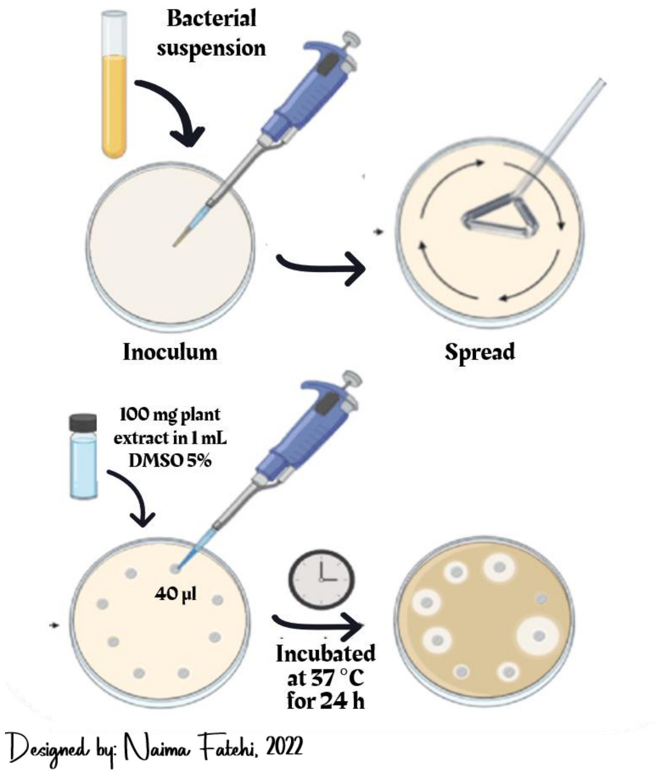

Figure II.9. *In vitro* Antibacterial Activity of Plant Extracts

VI. *IN VITRO* ANTIFUNGAL ACTIVITY

Plant products traditionally used as effective antifungal agents, are considered to be a part of the preformed defense system of higher plants and therefore, expected to deliver new active antimicrobial compounds (Bakkali et al., 2008; Sabulal and Varughese, 2009). In this perspective, there is an increasing demand for novel and effective antifungal agents, justifying the intense search for new drugs from various sources including natural products that are more effective and less toxic than those already in use (Mohd et al., 2013).

The antifungal screening of aqueous and hydromethanolic extracts of the investigated medicinal plants was evaluated, using the radial growth method on solid medium, against seven fungal pathogens isolated from local Wheat, toasted and green Coffee beans.

VI.1. Pathogenic Fungi Associated with Wheat and Coffee Beans

Wheat and Coffee beans are subject to various operations of contamination by microorganisms during growth (while seeds are on trees), after harvesting (when seeds are de-hulled, washed, and stored), and during storing.

Three samples were investigated in this study: local wheat, roasted and green coffee beans, they were collected randomly from local markets in Bechar Province in February 2016 and the experiment was carried out for three months (February, March, and April) in 2016 at Biology Laboratory, Tahri Mohammed University, Bechar.

The samples were homogenized and then divided into three equal sub-samples and labeled.

VI.1.1. Isolation of Fungal Strains

The dilution method (or indirect method) was employed for the isolation of fungal strains from local wheat, roasted and green coffee beans (Multon, 1982); suspensions (5 g of each sample + 45 mL of physiological water + a few drops of Tween 80) was diluted up to 10^{-5}. The aliquots were cultured for fungus on PDAa (Potatoes Dextrose Agar acidified) and DRBC (Dichloran Rose Bengal Chloramphenicol) media. For primary isolation, Rose Bengal (30mg/L) was also added to the medium (Larpent, 1990).

Three plates from each sample were incubated for 5 to 7 days at 25±2 °C, and each morphologically unique fungal colony was sub-cultured and purified using standard techniques.

VI.1.2. Identification and Characterization of Fungal Strains

The fungal species were identified and characterized based on their morphological characteristics (colony growth (length and width), presence or absence of aerial mycelium, colony color, presence of wrinkles and furrows, pigment production, etc.) and microscopic analysis by using taxonomic guides and standard procedures (Barnett and Hunter, 1972; Domsch et al., 1980; Ellis, 1976; Gilman, 1944).

The confirmation of genera was realized by the microculture method described by (Barnett and Hunter, 1972), whereas, the confirmation of species was carried out by the Single Spore method described by (Pitt, 1973) and (Ramirez, 1982), using three cultures media: CDA (Czapek Dextrose Agar), CYA (Czapek Yeast Agar) and MEA (Malt Extract Agar).

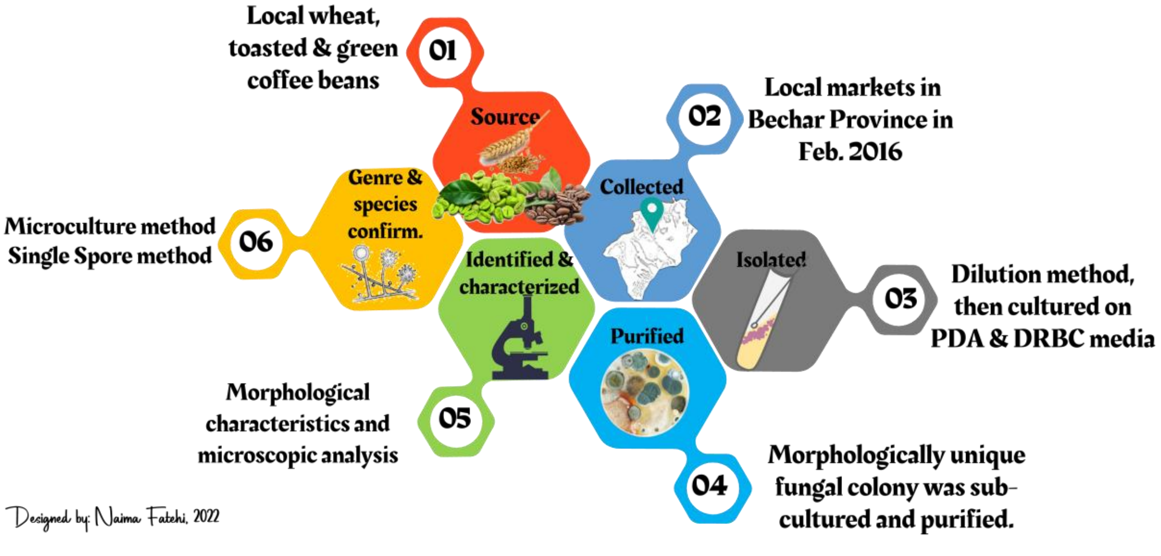

Figure II.10. Isolation and Identification of Pathogenic Fungi

VI.2. Investigated Fungal Strains

Out of the twenty-isolated fungal strains, seven pathogenic species (*Aspergillus flavus, A. nidulans A. niger, A. ochracus, Penicillium chrysogenum, P. digitatum,* and *P. oxalicum*) were used to evaluate the antifungal activity of the selected medicinal plants. All fungi were stored on Sabouraud Dextrose Agar slants in the refrigerator at 4 °C prior to use.

VI.3. Antifungal Activity of Plant Extracts

The antifungal activity was determined by using the radial growth method on a solid medium (Bajpai et al., 2007; Banso et al., 1999; Zambonelli et al., 1996). Briefly, 1 mL of 100 mg/mL (w/v) of each plant extract was introduced in tubes containing 19 mL of sterile acidified Potato Dextrose Agar (PDAa). After agitation, the mixture was poured into different Petri dishes and allowed to solidify. The mycelial felt (0.5 cm diameter) of each pathogenic fungus was transferred aseptically to the center of Petri dishes. A control experiment was performed without the extracts. Petri plates were incubated for 7days at 25 ± 2°C.

The inhibition percentage of mycelial growth of each extract was calculated using the following formula: ($PI = ((D_T - D)/D_T) \times 100$) where D_T is the diameter of mycelial growth in control and D is the diameter of mycelial growth in treatment (Pandey et al., 1982; Singh et al., 2009).

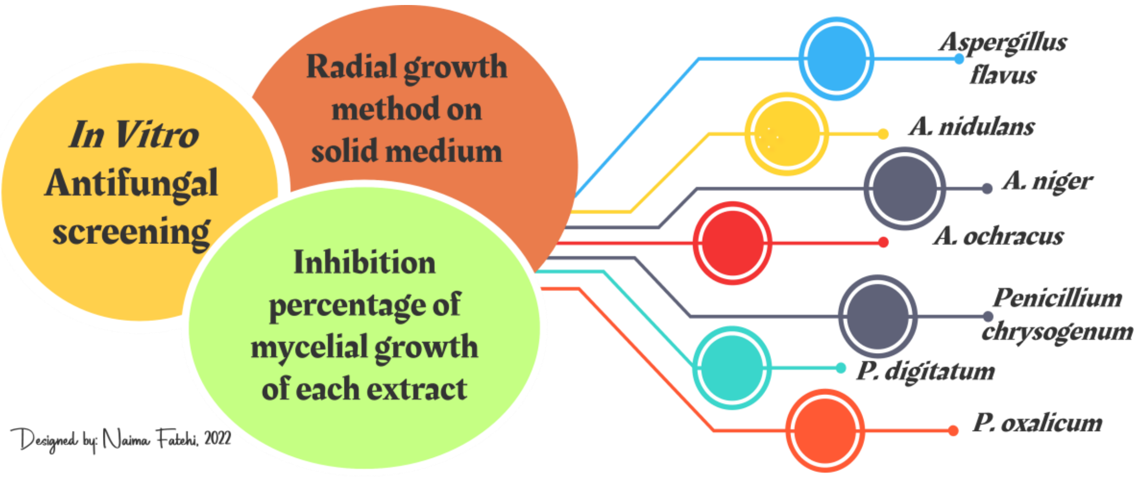

Figure II.11. *In Vitro* Antifungal Activity

VII. Statistical Analysis

All data were expressed as the mean ± standard deviation (SD) by measuring three independent replicates. One-way analysis of variance (SAS, 1990; ANOVA procedure) was performed to compare means and to test the significance of differences between means obtained among the treatments at $p < 0.05$ level of significance.

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Chapter 3

Results

&

Discussion

I. INTRODUCTION

Many populated groups in developing countries still rely on traditional medicine to prevent and treat different illnesses, despite the advances made in modern medicine. This is often because of cultural beliefs, low cost, and effectiveness (Makhuvele et al., 2020; Tabassum and Vidyasagar, 2017; Telichowska et al., 2020).

However, in the case of many Algerian endemic medicinal plants, no such detailed studies are available. Therefore, there is a need for systematic evaluation of these medicinal plants. Keeping all these facts in view, this study is carried out to establish a preliminary ethnobotanical database for local plants traditionally used in human therapy in the Bechar region, and evaluate the phytochemical, antioxidant, and anti-microbial properties of nine ethno-therapeutically important medicinal plants, namely *A. nardus*, *A. schoenanthus*, *G. alypum*, two species of *H. scoparia*, *P. laevigata*, *R. tripartita*, *T. gallica*, and *T. nudatum*. All these species are used traditionally for treating various ailments in the southwest Algeria region.

II. ETHNOBOTANICAL STUDY

The present study was carried out to establish a preliminary ethnobotanical database for the spontaneous medicinal plants traditionally used in human therapy in the region of Bechar. The fieldwork was conducted between June 2013 and July 2015.

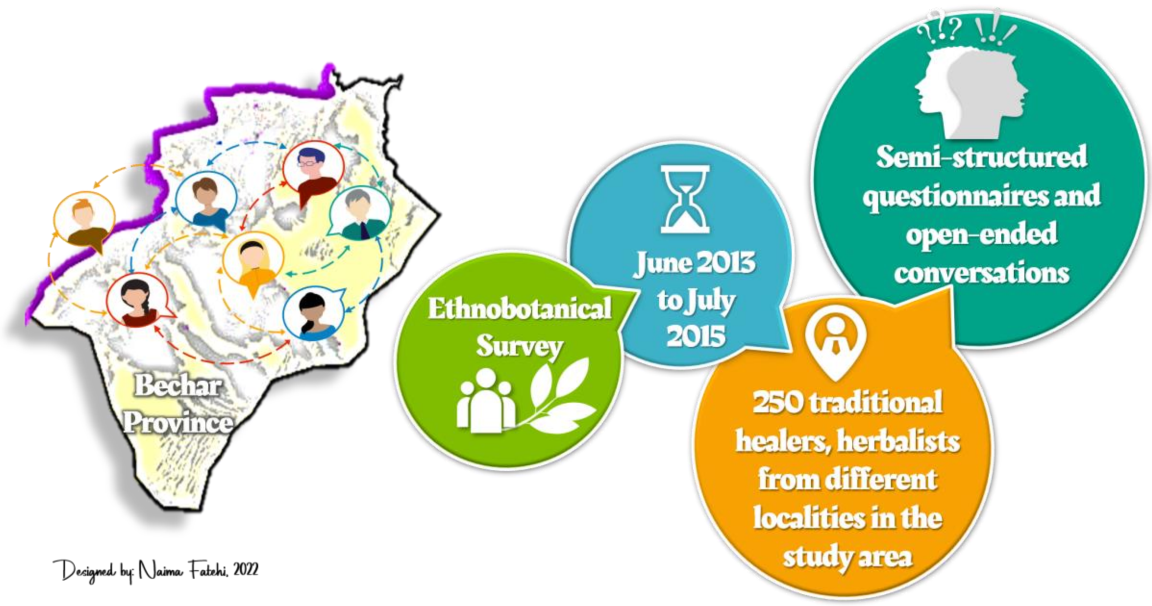


Figure III.1. Ethnobotanical Survey

More than 250 selected informants aged between 20 and 77 years contributed to the information (Table III.1). The study showed that people older than 40 years of age have a frequency of use of medicinal plants by 80%. It has been noted also that 51% of plant users refer to their own experiences and those of ancestors in the use of medicinal plants as remedies, 32% solicit herbalists while 18% consults books, media, and websites specializing in herbal medicine.

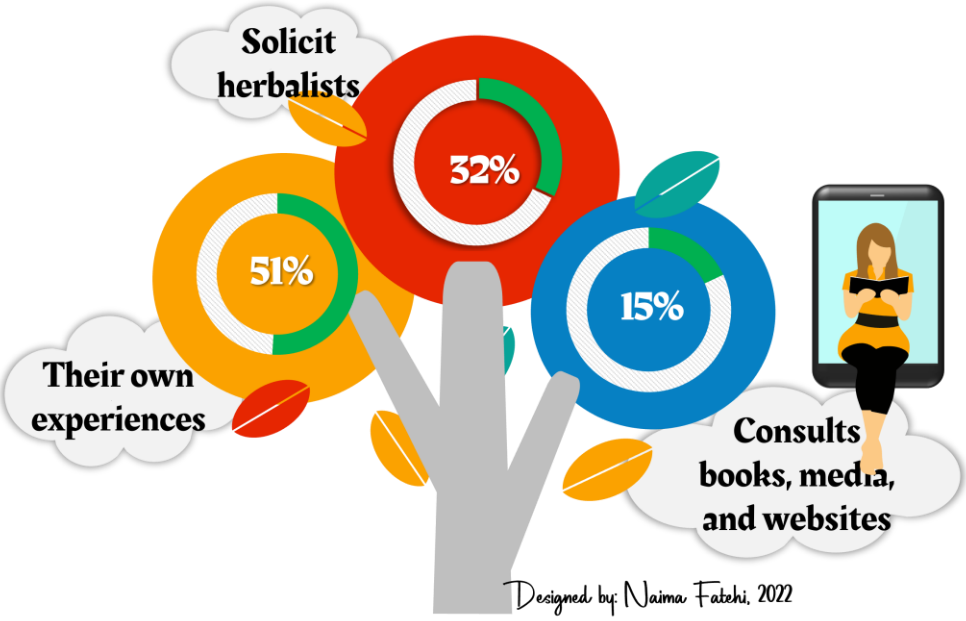


Figure III.2. Informants Acquired Experience

The results show that women had more knowledge of medicinal species by 67% against 33% for men. Women were more interested in plants for medicinal and cosmetic purposes, they learn from members of their families mainly grandparents and parents through routine practices. These results are in line with results of the studies realized in many regions of Algeria, showing that the use of medicinal plants is higher in women than men (Baziz et al., 2020; Benaiche et al., 2019; Bouallala et al., 2014; Chohra and Ferchichi, 2019; Djahafi et al., 2021; Lazli et al., 2019; Sarri et al., 2014; Souilah et al., 2018).

Table III.1. Demographic Profile of Medicinal Plants Users

Variables	Abundance	Relative abundance (%)
Age		
20-39	45	18%
40-60	151	60%
>60	54	22%
Gender		
Female	168	67%
Male	82	33%
Marital status		
Married	192	77%
Single	58	23%

It is evident from the interviews conducted; knowledge of medicinal plants is limited to traditional healers, herbalists, and elderly persons, especially those living in rural areas, due to a lack of interest among the younger generation. For young people, this choice could be justified by the lack of information on the importance of plants and also by the lack of confidence in the curative efficacy of traditional medicine (Hachlafi et al., 2020).

Another possible explanation for this is that young people often have other activities and have very little time to spend with the older knowledgeable persons. The information acquired by the youngest deteriorates as they engage in other activities.

Rebbas et al. (2012) concluded that ‘an integrated strategy for conservation of biodiversity must be installed’ (Rebbas et al., 2012). This might be done by increasing ethnobotanical studies which allow better management of gathering of plants or by promoting the cultivation of certain species with great medicinal and economical potential.

According to the survey, families’ situation has a very important role in the use of medicinal plants: 77% of married people use plants to heal themselves against 23% of single people, this is explained by the fact that married people rely on themselves. Secondly, it is possible to reduce the burden of the doctor and the pharmacist.

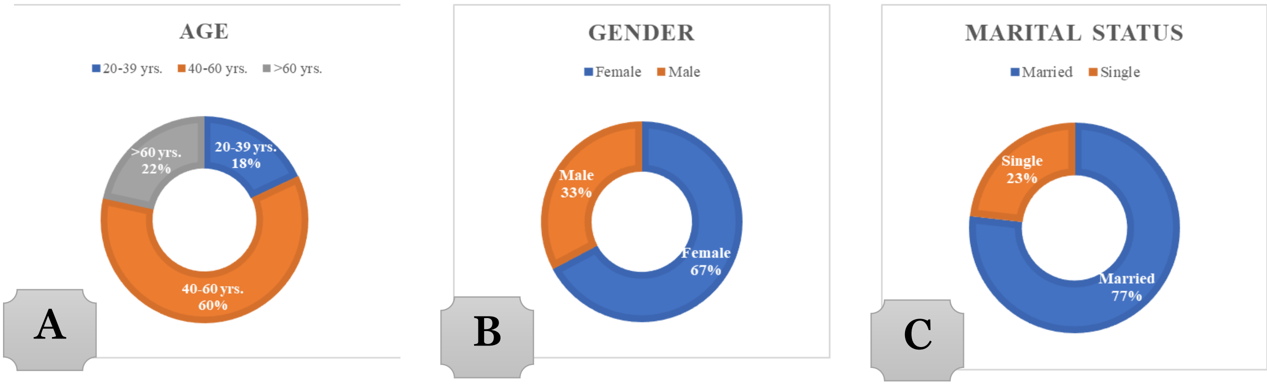


Figure III.3. Informants Profile Results (A: Age, B: Gender, C: Marital status)

A total of 162 species of medicinal plant belonging to 143 genera and 50 families were recorded in the study area. This indicates the high diversity of medicinal plants in the studied region. According to the interviewed informants and the flora of Algeria references (Ozenda, 1977; Quezel and Santa, 1963), 127 of the species listed in this study are spontaneous (78%), some of them have little data or have never been studied, whereas the others (35 Spp., 22%) are locally cultivated.

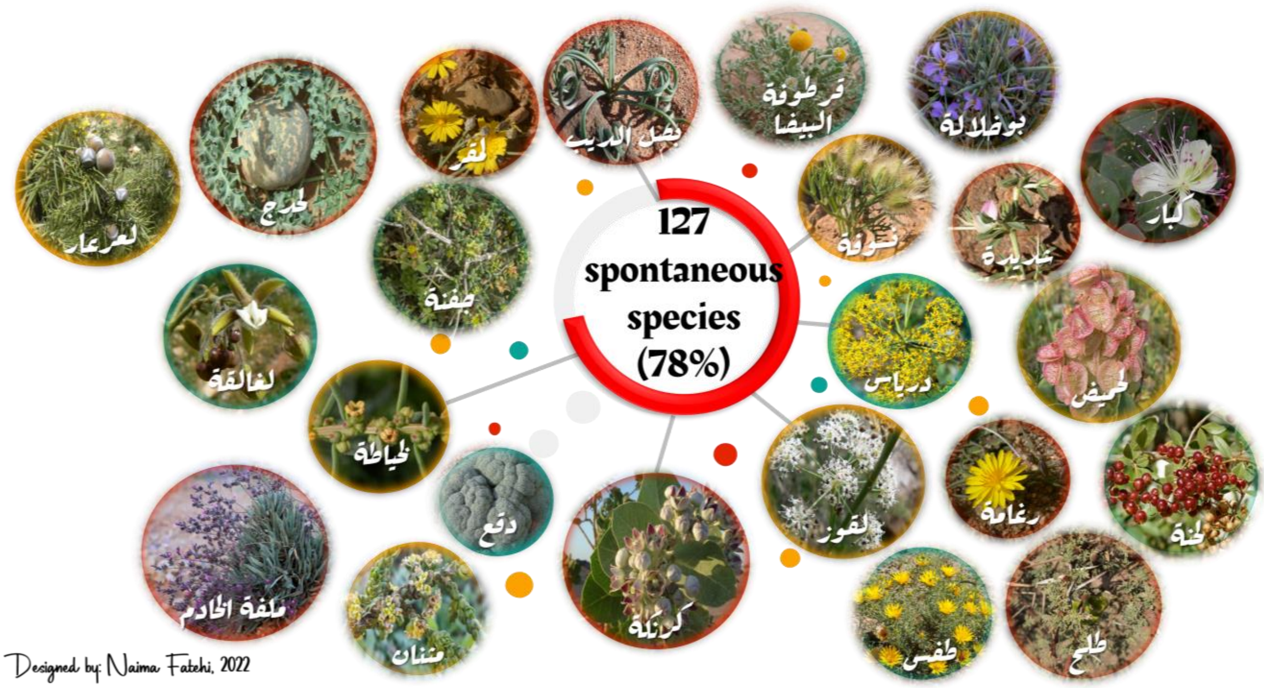


Figure III.4. Some Mentioned Medicinal Plants in the Survey

The major plant families which contributed to folk medicine were Asteraceae (18 spp., 11%), Apiaceae & Lamiaceae (12 spp., 7% each), Fabaceae (10 spp., 6%), Brassicaceae, Chenopodiaceae & Poaceae (9 spp., 6% each), Cucurbitaceae, Liliaceae & Rosaceae (6 spp., 4% each), Solanaceae (4 spp., 3%), Anacardiaceae, Asclepiadaceae, Convolvulaceae, Euphorbiaceae, Malvaceae, Rutaceae & Zygophyllaceae (3 spp., 2% each), Caryophyllaceae, Cupressaceae, Moraceae, Oleaceae, Palmaceae, Pinaceae, Resedaceae & Tamaricaceae (2 spp. each) while remaining 23 families had one species each.

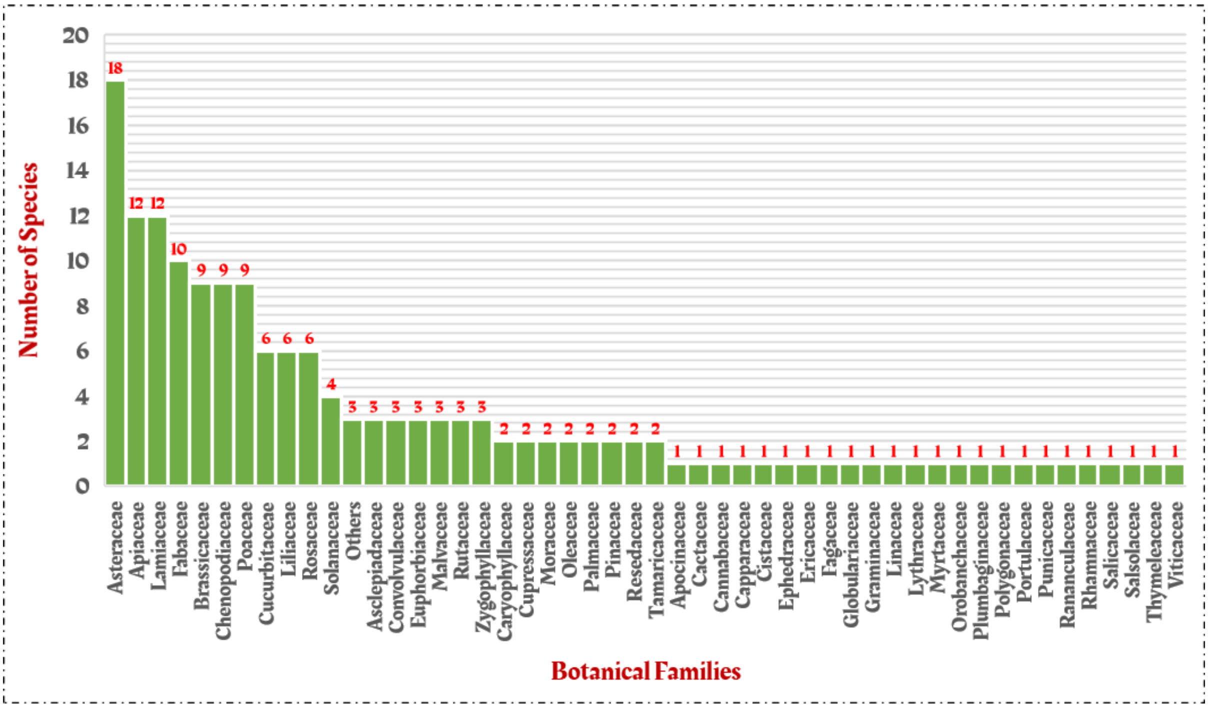


Figure III.5. Distribution of Species by Botanical Family.

In the current study, Asteraceae, Apiaceae, Lamiaceae, and Fabaceae represent more than 31% of all the species listed. This can provide a good indication of deep knowledge of plants and the development of this flora by the local populations for their different needs. Similar studies were conducted on a national scale revealed the strong contribution of these families to the traditional Algerian pharmacopeia (Chohra and Ferchichi, 2019; Djahafi et al., 2021; Lazli et al., 2019).

Furthermore, according to many studies, botanical families such as Asteraceae, Poaceae, and Fabaceae are considered among the most exploited families in traditional medicine (Ouled Dhaou et al., 2010).

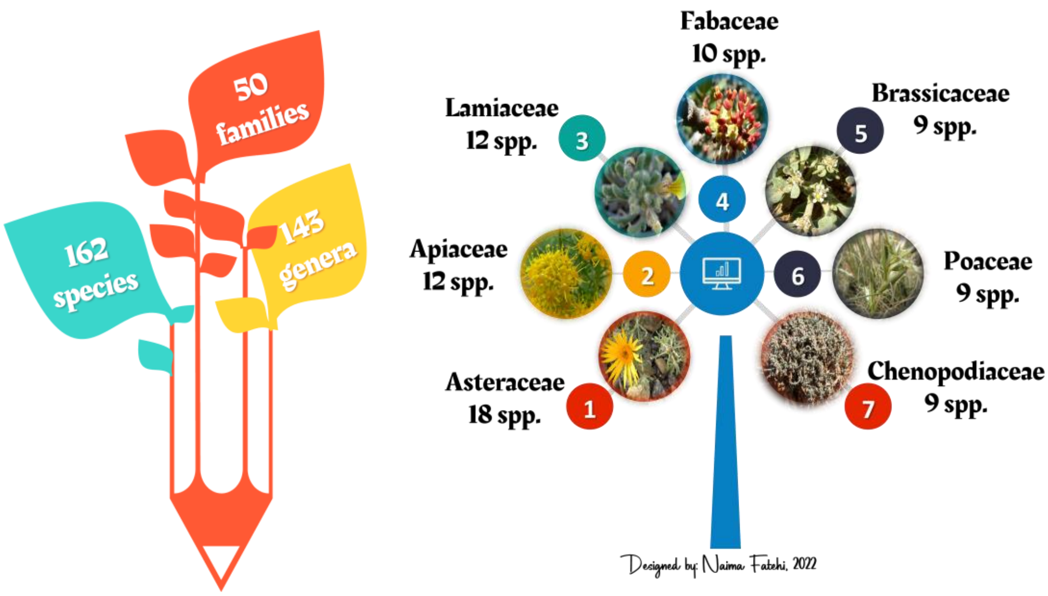


Figure III.6. Most Plant Families Contributed to Local Folkloric Medicine

Thirteen different parts of plants were clearly reported to be used for medicinal purposes: Bark, Bulbs, Flowers, Fruits, Gum, Latex, Leaves, Pericarps, Resin, Rhizome, Roots, Seeds and Stems (Figure III.7). About 41% of the species were used for their leaves followed by aerial part (29%), fruits (24%), seeds (22%), roots (21%), entire plant and stems (8% each), flowers (6%), latex, Bark and resin (4% each), Bulbs and Pericarps (2% each), Gum and Rhizome (1% each).

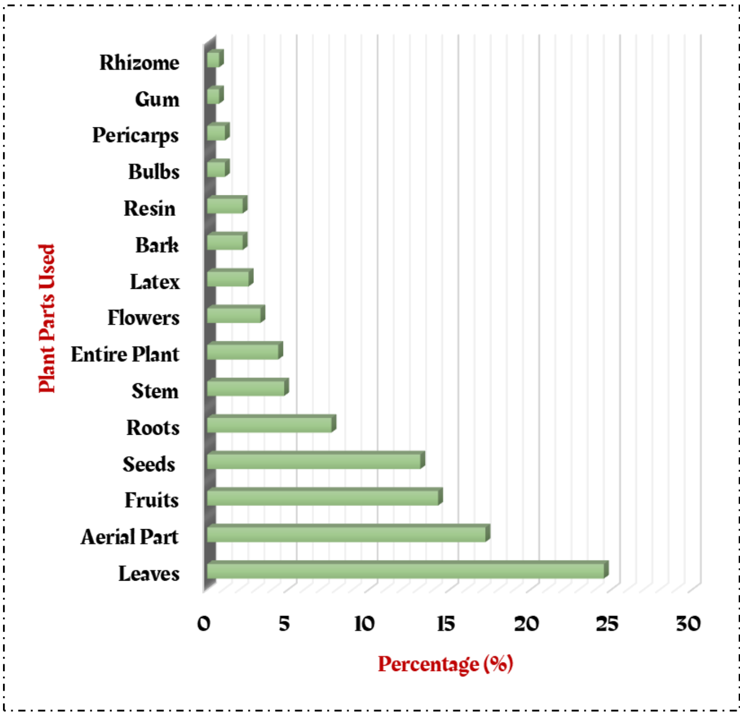


Figure III.7. Frequency of Plant Parts Used in The Survey

This is consistent with the results of several studies which report that the leaves are frequently used in medicinal recipes (Bouafia et al., 2021; Fanou et al., 2020; Miara et al., 2020; Rachid et al., 2012; Sarri et al., 2014). The frequent use of leaves and seeds is explained by: the ease of their obtaining at the herbalist; the ease and the speed of their harvest, the ease of their storage anytime and anywhere; and the fact that the leaves are the seat of the photosynthesis and storage of the majority of bioactive secondary metabolites (Chohra and Ferchichi, 2019; Fanou et al., 2020).

In fact, different parts of the same plant may have different chemical compositions and do not have the same action. The predominance of the use of a member with respect to another in the field of therapeutics is derived from the concentration of active ingredients in this organ. Active principles can be found in all parts of the plant, but unevenly. And all the active ingredients in the same plant do not have the same properties (Bouafia et al., 2021; Bruneton, 1999; Chohra and Ferchichi, 2019; Hosseini et al., 2021; Moussaoui et al., 2014).

Turning to the different ways of remedy preparation, the decoction is the main mode of preparation used (83%), followed by cataplasm (35%), powder (28%), raw (27%), Infusion (13%), Maceration (7%) and oil (2%). It is often reported that the decoction collects the most active substances and mitigates or cancels the toxic effect of certain ailments (Bouafia et al., 2021; Salhi et al., 2010; Sarri et al., 2012). It was also observed that some plants were used in more than one form of preparation.

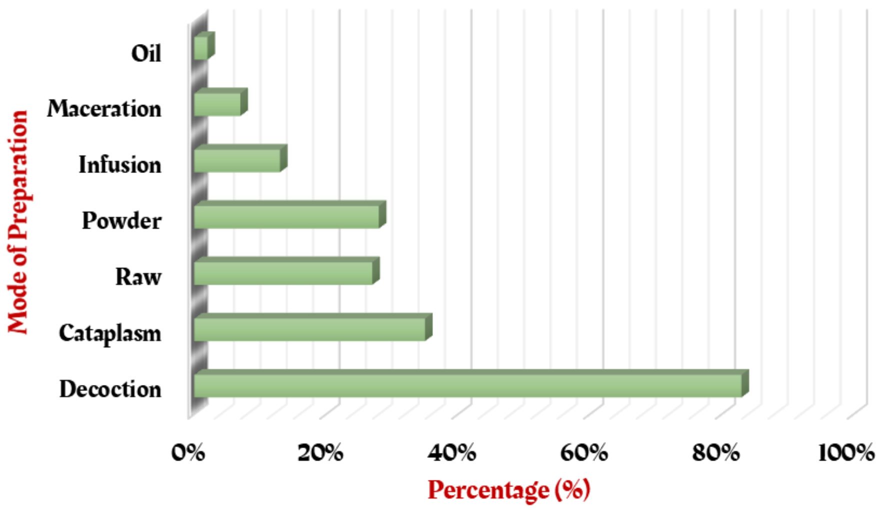


Figure III.8. Frequency of Preparation Modes Used

Most preparations were drawn from a single plant (85%), but their mixtures were also commonly used. This indicates that monospecific recipes are much easier and quicker to prepare for remedy than the other recipes. Objectively, due to the interactions that can occur between compounds from several plants, recipes made up of more than three plants should be used with caution and sparingly.

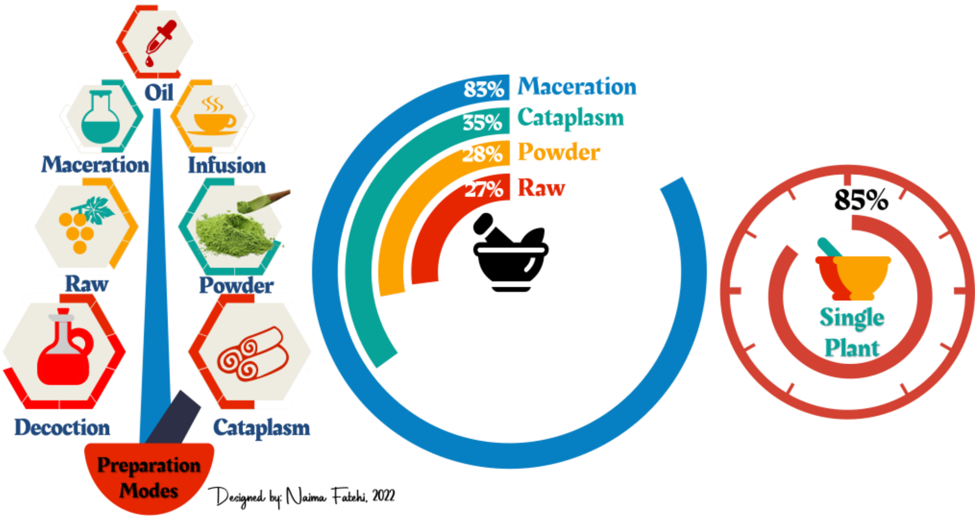


Figure III.9. Most Used Preparation Modes

According to the study, the great majority of the remedies were taken orally (95%). The external application was also employed, accounting for 51%, and may consist, generally, in a local application to the affected part. However, other modes of administration by different routes are used as follows: mouthwash (14%), mask (12%), eardrops (6%), fumigation (4%) and eye drops (2%). It was observed that some plants were prepared using more than one method and, in some cases, more than one plant part was used.

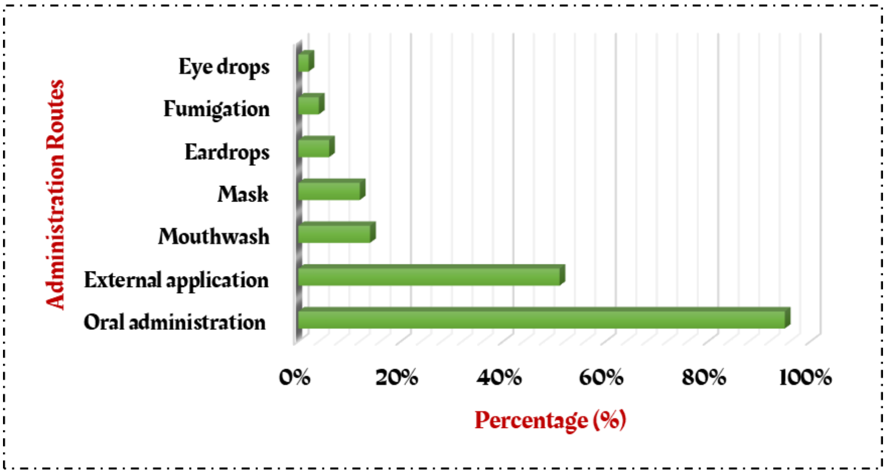


Figure III.10. Frequency of Administration Routes

Various ethnobotanical surveys conducted worldwide have reported similar observations. This result could be explained by the fact that the local population is mainly affected by internal diseases which could favor oral administration (Baziz et al., 2020; Bouafia et al., 2021; Hachlafi et al., 2020; Lazli et al., 2019). Besides, this route can be the most practical, the safest, and above all, the least expensive. Another possible explanation for this may be related to the addition of some solvents or additives such as water which are believed to increase extraction of bioactive molecules during remedy preparation while minimizing their harmful and toxic effects.

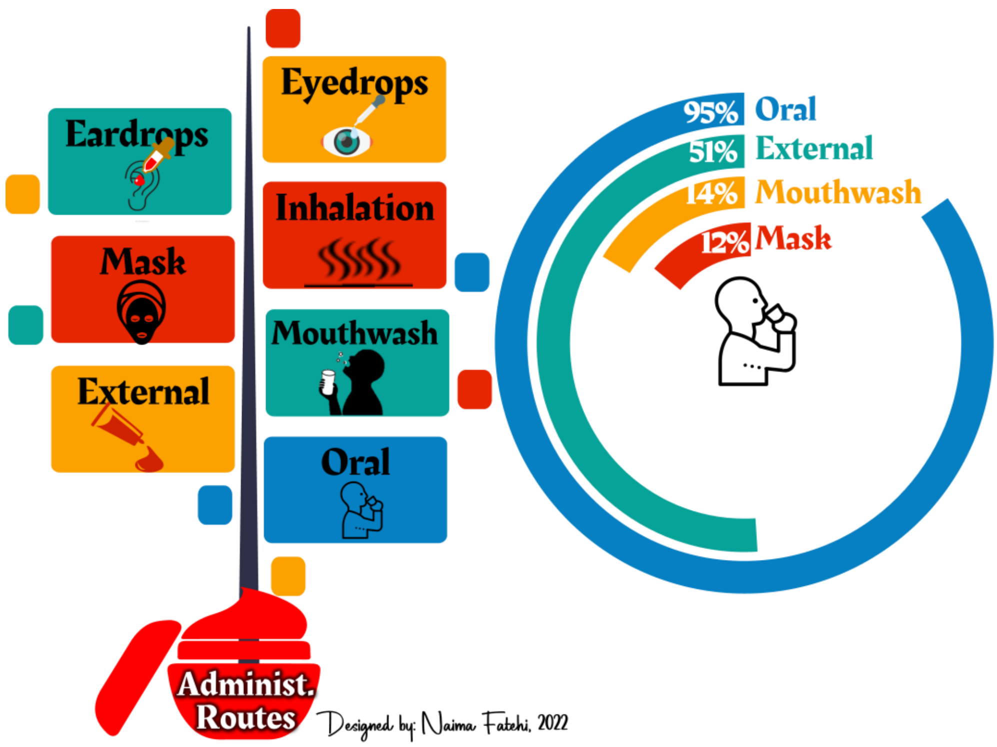


Figure III.11. Most Used Administration Routes

On the other hand, most of the informants were found to have known little about the dosage. In general, the prescribed dosage tends to be seemingly arbitrary, and there seem to be no standardized dosage prescriptions. However, most of the informants interviewed agree that the dose prescriptions increase with the severity of disease and age. They generally used measuring units such as teaspoons, cups, and fingers.

Table III.2. Medicinal Plants Used in the Folk Medicine in the Bechar Region.

N°	Family name	Botanical name	Vernacular Name	Used Parts	Medicinal Uses	Prep.	Admin.	PRK (%)	IV_s
1	Anacardiaceae	***Pistacia atlantica* Desf.**	بطمة	Fruits, Leaves, Gum	Helminthiasis, stomach pains, colic, gastrointestinal disorders, vomiting, gum and tooth ailments, asthma, hair problems	Cataplasm Decoction Powder	External use Fumigation Mask Mouth wash Oral	15	0.2
2	Anacardiaceae	***Pistacia lentiscus* L.**	ضرو	Leaves, Resin	Stomach pains, mouth and tooth care, vomiting, labor pains, asthma	Decoction	Mouth wash Oral	15	0.1
3	Anacardiaceae	***Rhus tripartita* R. Sch.**	جداري، تيزغا	Bark, Leaves, Fruits	Gastrointestinal disorders, diabetes, colic, diarrhea, rheumatism, joints and muscular pains, stimulant, Tooth pains, insect bites, and stings	Decoction Raw	External use Mouth wash Oral	23	0.2
4	Apiaceae	***Ammodaucus leucotrichus* Coss. & Dur.**	نسوفة، مودريقة	Fruits, Seeds	Allergy, appetizer, colic, cough, diarrhea, vomiting, helminthiasis, hypotension, labor pains, earache, pulmonary infections, stomach pains	Decoction Raw	Ear drops Oral	31	0.3
5	Apiaceae	***Anethum graveolens* L.**	شبت	Aerial part, seeds	Oliguria, hepatitis, vomiting, ingestion, flatulence	Infusion	Oral	11	0.1
6	Apiaceae	***Apium graveolens* L.**	كرافس	Aerial Part	Aphrodisiac, bladder diseases, kidney stones, prostate pains, urinary infections, appetizer, constipation, anemia, rheumatism, food poisoning	Decoction Raw	Oral	15	0.1
7	Apiaceae	***Carum carvi* L.**	لكروية العمية	Seeds	Aphrodisiac, diabetes, flatulence, colds, stomach pains	Decoction	Oral	15	0.1
8	Apiaceae	***Coriandrum sativum* L.**	قسبر	Aerial Part, Seeds	Aphrodisiac, bladder diseases, gastrointestinal disorders, insomnia, rheumatism, diarrhea, sedative, stomach pains, flatulence, colic, diabetes	Decoction Raw	Oral	11	0.1
9	Apiaceae	***Daucus carota* L.**	جزر، زرودية	Seeds, Fruits, Roots	Stomach pains, helminthiasis, diabetes, sedative, aphrodisiac, amelioration of vision, eczema	Decoction Raw	External use Oral	11	0.1

N°	Family name	Botanical name	Vernacular Name	Used Parts	Medicinal Uses	Prep.	Admin.	PRK (%)	IV_s
10	Apiaceae	***Ferula asafoetida* L.**	حنطيط	Resin	Diabetes	Decoction	Oral	15	0.1
11	Apiaceae	***Ferula communis* L.**	كلخ، نرد، الفاسوخ	Resin	Female sterility, appetizer, sedative, diabetes, Rheumatism, cancer	Decoction	Oral	15	0.1
12	Apiaceae	***Foeniculum vulgare* Mill.**	نافع، بسباس	Seeds, Leaves	Flatulence, cough, gastrointestinal disorders, galactagogue, kidney pains, stimulant, diabetes	Decoction Maceration Raw	Oral	32	0.3
13	Apiaceae	***Petroselinum crispum* Mill.**	معدنوس	Arial part, Fruits	Flatulence, oliguria, expectorant, stomach pains, diabetes, kidney pains	Decoction Raw	Oral	15	0.1
14	Apiaceae	***Pituranthos scoparius* Benth. & Hook.**	قوزة	Aerial Part	Rheumatism, sexual impotence, gastrointestinal disorders, bilious troubles, colds, gynecological pains, labor pains, asthma, diabetes, hepatitis, urinary infections, insect bites, and stings	Cataplasm Decoction	External use Oral	15	0.1
15	Apiaceae	***Thapsia garganica* L.**	درياس، بونافع	Roots, Leaves	Cough, cancer, rheumatism, sterility, bladder diseases, liver pains	Cataplasm Decoction	External use Oral	15	0.1
16	Apocinaceae	***Nerium oleander* L.**	دفلة	Leaves, Latex, Seeds	Headache, diabetes, colds, rheum, cough, rheumatism, oliguria, tooth pains, vertigo, food poisoning, syphilis, analgesic, eczema, abortifacient, skin cancer, baldness	Cataplasm Decoction Infusion	External use Mouth wash Oral	15	0.1
17	Asclepiadaceae	***Calotropis procera* Ait.**	كرنكة	Leaves, Latex, Roots	Abortifacient, asthma, constipation, cough, eczema, epilepsy, fever, helminthiasis, rheumatism, skin parasites, stomach pains, syphilis, tonsillitis, warts, wounds healing	Cataplasm Decoction	External use Oral	22	0.2
18	Asclepiadaceae	***Pergularia tomentosa* L.**	لغالقة	Aerial Part, Latex	Influenza, constipation, eczema, burns, allergy, helminthiasis, abortifacient, ringworm, abscesses, tooth pains	Cataplasm Decoction	External use Mouth wash Oral	11	0.1
19	Asclepiadaceae	***Periploca laevigata* Ait.**	الحلاب	Bark, Leaves	Rheumatism, insect bites, and stings, hypertension, bronchitis, abortifacient, diabetes, weight loss, hypocholesterolemia	Cataplasm Decoction	External use Oral	23	0.2
20	Asteraceae	***Anvillea Radiata* Coss. & Dur.**	نقد	Flowers, Leaves, Stem	Food poisoning, cancer, urinary infections, prostate pains, kidney pains, asthma	Decoction	Oral	32	0.3

N°	Family name	Botanical name	Vernacular Name	Used Parts	Medicinal Uses	Prep.	Admin.	PRK (%)	IV_s
21	Asteraceae	***Artemisia arborescens* L.**	شيبة	Aerial Part	Antiseptic, food poisoning, flatulence, colds, eczema, oliguria, fever, cardiac ailments, hypertension, laxative, earache, stomach pains, helminthiasis	Decoction Infusion	External use Ear drops Oral	57	0.6
22	Asteraceae	***Artemisia campestris* L.**	ألال	Aerial Part	Colds, analgesic, gastrointestinal disorders, helminthiasis, insect bites and stings, skin facial care, diabetes	Decoction Powder	External use Mask Oral	15	0.1
23	Asteraceae	***Artemisia herba alba* Asso.**	شيح	Aerial Part	Flatulence, bilious troubles, colds, oliguria, period pains, gastrointestinal disorders, diabetes, obesity, respiratory infections, rheumatism, sedative, stomach pains, helminthiasis	Decoction Infusion Powder	Fumigation Oral	31	0.3
24	Asteraceae	***Atractylis gummifera* L.**	أداد	Roots	Abscesses, warts, Abortifacient, vomiting, labor pains	Decoction Powder	Fumigation Oral	15	0.1
25	Asteraceae	***Bubonium graveolens* Forsk.**	طفس	Leaves	Diarrhea, gum and tooth ailments, colds, rheumatism, varicose	Decoction	Mouth wash Oral	31	0.3
26	Asteraceae	***Chrysanthemum macrocarpum* Coss. subsp.**	بوشيشة	Aerial Part	Colds, indigestion, period pains, helminthiasis, wounds healing, stomach pains	Cataplasm Decoction Maceration	External use Oral	12	0.1
27	Asteraceae	***Cotula cinerea* Del.**	قرطوفة البيضا	Entire Plant	Colic, diarrhea, cough, colds, pulmonary infections, joints inflammations, ophthalmia, kidney pains, period pains, headache, measles, teething, fever, sore throat, itchy skin	Decoction Infusion Powder	External use Oral	49	0.5
28	Asteraceae	***Cynara cardunculus* L.**	خرشف	Leaves, Roots	Fever, diarrhea, stomach pains	Decoction	Oral	10	0.1
29	Asteraceae	***Echinops spinosus L.***	تسكرة، شوك لحمير	Aerial Part	Colds, kidney stones, oliguria, diabetes, abortifacient, labor pains, fatigue, fever	Decoction Powder	Oral	10	0.1
30	Asteraceae	***Helianthus annuus* L.**	عباد الشمس	Seeds, Roots	Malaria, oliguria, hypercholesterolemia, gum inflammation	Decoction Powder	Mouth wash Oral	13	0.1
31	Asteraceae	***Launaea nudicaulis* (L.) Hook.**	رغاية	Aerial Part	Pulmonary infections, indigestion, period pains, helminthiasis, wounds healing,	Cataplasm Decoction	External use Oral	15	0.2

N°	Family name	Botanical name	Vernacular Name	Used Parts	Medicinal Uses	Prep.	Admin.	PRK (%)	IV_s
					stomach pains, gastric burns, constipation, hemorrhoids, fever, itchy skin, eczema	Maceration			
32	Asteraceae	***Launaea resedifolia* L.**	لقر	Aerial Part	Pulmonary infections, period pains, helminthiasis, stomach pains, hepatitis	Decoction Maceration	Oral	5	0.1
33	Asteraceae	***Launeae arboresens* (Batt.) Murb.**	ام لبينة	Aerial Part, Latex, Roots	Weaning, Diabetes, diarrhea, fever, stomach pains, fever, helminthiasis, sore throat, Abscesses, food poisoning	Cataplasm Maceration	External use Oral	31	0.3
34	Asteraceae	***Matricaria pubescens* (Desf.) Schultz.**	وزوازة	Aerial Part, Flowers	Measles, fever, sore throat, itchy skin, stomach pains, colic, tooth pains, ulcers, asthma, flatulence, gastrointestinal disorders, fatigue, rheum, appetizer, helminthiasis, period pains, cough, kidney pains, rheumatism, colds	Decoction Powder Raw	External use Mouth wash Oral	31	0.3
35	Asteraceae	***Rhetinolepis lonadioides* Coss.**	كمون العشار	Aerial Part	Stomach pains, Cardiotonic, Rheumatism, pulmonary infections, stimulant	Decoction	Oral	10	0.1
36	Asteraceae	***Scorzonera undulata* Vahl.**	القيز	Entire Plant	Anemia, Stimulant, intestinal pains	Decoction Raw	Oral	15	0.2
37	Asteraceae	***Woronia saharae* Benth. & Coss.**	كبار المعين، فسفاس	Leaves, Stem	Joint's inflammations, diabetes, cardiac ailments, colds, gastrointestinal disorders, icterus	Decoction	Oral	22	0.2
38	Brassicaceae	***Anastatica hierochuntica* L.**	كف مريم، كمشة	Aerial Part	Colds, constipation, epilepsy, female sterility and male impotency, labor pains, period pains, rheumatism	Decoction	Oral	22	0.2
39	Brassicaceae	***Brassica oleracea* L.**	اللفت	Fruits, Seeds, Leaves	Cough, kidney stones, asthma, acne	Decoction Raw	Oral	10	0.1
40	Brassicaceae	***Brassica repa* L.**	كرنب، ملفوف	Leaves, Fruits	Tumors, asthma, analgesic, diabetes, eczema, gastrointestinal disorders, hoarseness, insomnia, prostate pains, rheumatism, wounds healing	Cataplasm Decoction Raw	External use Oral	13	0.1
41	Brassicaceae	***Diplotaxis harra* (Forssk.) Boiss.**	حارة	Aerial Part	Diabetes, constipation, ulcers, colds	Decoction	Oral	15	0.2

N°	Family name	Botanical name	Vernacular Name	Used Parts	Medicinal Uses	Prep.	Admin.	PRK (%)	IV_s
42	Brassicaceae	***Eruca vesicaria* Cav.**	جرجير	Entire Plant	Diabetes, kidney stones, liver pains, oliguria, hair problems, skin diseases, gum and tooth ailments, burns	Cataplasm Infusion	External use Mouth wash Oral	23	0.2
43	Brassicaceae	***Farsetia aegyptiaca* Turra.**	لعود الأبيض	Entire Plant	Colic, stomach pains, gum and tooth ailments	Decoction	Mouth wash Oral	10	0.1
44	Brassicaceae	***Moricandia arvensis* (L.) DC.**	كرم الجمل	Leaves	Syphilis	Decoction	Oral	10	0.1
45	Brassicaceae	***Raphanus sativus* L.**	الفجل	Seeds	Diabetes, gastrointestinal disorders	Raw	Oral	10	0.1
46	Brassicaceae	***Zilla macroptera* Coss.**	بوخلالة	Leaves, Stem	Skin diseases	Cataplasm	External use	15	0.1
47	Cactaceae	***Opuntia ficus-barbarica* Mill.**	هندية	Flowers, Fruits, Leaves, Stem	Colds, diarrhea, hair problems, kidney pains, stomach pains, cough	Decoction	Mask Oral	15	0.1
48	Cannabaceae	***Cannabis sativa* L.**	لكيف	Seeds, Leaves	Hair problems, bilious troubles, skin diseases, hallucinate	Cataplasm Powder Raw	External use Oral	10	0.1
49	Capparaceae	***Capparis spinosa* L.**	كبار، كبار سيد الشيخ	Leaves, Flowers, Roots	Cancer, bilious troubles, colds, tumors, flatulence, headache, kidney pains, prostate pains, liver insufficiency, migraine, rheumatism, spleen swelling, tuberculosis, anemia, diabetes, stomach pains	Decoction	Oral	31	0.3
50	Caryophyllaceae	***Gymnocarpos decander* Forsk.**	جفنة	Aerial Part	Psychosomatic diseases, break down	Powder	Fumigation	15	0.2
51	Caryophyllaceae	***Herniaria glabra* L.**	فتات الحجر	Entire Plant	Kidney stones, pancreas ailments, colds, urinary infections, skin and face care, hypertension	Decoction	Mask Oral	22	0.2
52	Chenopodiaceae	***Anabasis aretioides* Bunge.**	دقع، صلاع، الشجرة اللي ما تهزها الريح	Aerial Part, Roots	Colic, eczema, fever, headache, stomach pains, colds, rheumatism, hemorrhoids	Powder	External use Oral	31	0.3
53	Chenopodiaceae	***Atriplex halimus* L.**	قطف، القطف المالح	Leaves	Tumors, diabetes, itchy skin, urinary retention, cancer, gastrointestinal disorders,	Decoction Powder	External use Eye drops	49	0.5

N°	Family name	Botanical name	Vernacular Name	Used Parts	Medicinal Uses	Prep.	Admin.	PRK (%)	IV_s
					eyes disorders		Oral		
54	Chenopodiaceae	***Beta vulgaris* L.**	باربا، البطراف	Aerial Part, Roots, Fruits	Eczema, baldness, liver pains, joints and muscular pains, hepatitis, kidney pains, headache, vaginal infections	Decoction Raw	External use Oral	13	0.1
55	Chenopodiaceae	***Chenopodium ambrosioides* L.**	مخينزة	Leaves, Seeds	Headache, cough, flatulence, colds, rheum, oliguria, joints inflammations, gastrointestinal disorders, period pains, helminthiasis, wounds healing	Cataplasm Decoction	External use Oral	31	0.3
56	Chenopodiaceae	***Cornulaca monacantha* Del.**	حاد	Aerial Part	Liver pains, eczema, abscesses, vomiting	Decoction	External use Oral	10	0.1
57	Chenopodiaceae	***Hammada Scoparia* Pomel.**	رمث	Entire Plant	Indigestion, tumors, eczema, wounds healing, insect bites and stings, diabetes, stomach pains, gastrointestinal disorders, food poisoning, colds, rheum, tooth pains, cancer	Cataplasm Decoction Powder Raw	External use Mouth wash Oral	51	0.5
58	Chenopodiaceae	***Salsola baryosma* (Schul.) Dandy.**	لغسال	Entire Plant	Hypertension, wounds healing, bruises, oedema	Cataplasm Decoction	External use Oral	15	0.1
59	Chenopodiaceae	***Spinacia oleracea* L.**	سلق	Leaves	Diabetes	Decoction	Oral	13	0.1
60	Chenopodiaceae	***Traganum nudatum* Del.**	ضمران	Aerial Part, Fruits	Diarrhea, rheumatism, wounds healing, Intestinal pains, constipation, joints and muscular pains, cancer	Cataplasm Decoction	External use Oral	23	0.2
61	Cistaceae	***Helianthemum eriocephalum* Pomel.**	رقيق	Leaves	Debility, colds	Decoction	Oral	15	0.1
62	Convolvulaceae	***Convolvulus althaeoides* L.**	لواية	Leaves, Stem, Roots	Stomach pains, constipation, colds, kidney pains	Decoction	Oral	9	0.1
63	Convolvulaceae	***Convulvus Arvensis* L.**	اللواي، اللبلاب	Leaves, Stem	Laxative, liver insufficiency, asthma, pulmonary infections, gastrointestinal disorders	Decoction	Oral	11	0.1
64	Convolvulaceae	***Ipomoea batatas (L.) Lam.***	بطاطا حلوة	Leaves, Fruits	Burns, insect bites and stings, wounds healing	Cataplasm	External use	5	0.1
65	Cucurbitaceae	***Citrullus colocynthis* Schrad.**	حدج، حنظل	Fruits, Seeds	Eczema, diabetes, genital infections, rheumatism, insect bites and stings, stomach	Cataplasm Maceration	External use Oral	32	0.3

N°	Family name	Botanical name	Vernacular Name	Used Parts	Medicinal Uses	Prep.	Admin.	PRK (%)	IVs
					pains, syphilis, tuberculosis, wounds healing, diarrhea	Powder			
66	Cucurbitaceae	***Citrullus lanatus* L.**	دلاع	Fruits, Seeds	Analgesic, oliguria, helminthiasis, hypotension	Raw	Oral	11	0.1
67	Cucurbitaceae	***Cucumis melo* L.**	لبتيخ	Seeds, Fruits	Gastrointestinal disorders, laxative, skin and face care, urinary infections, aphrodisiac	Powder Raw	Mask Oral	11	0.1
68	Cucurbitaceae	***Cucurbita pepo* L.**	لكابوية، القرعة	Seeds, Fruits	Oliguria, gastrointestinal disorders, Hypotension, prostate pains, skin diseases	Decoction Raw	External use Oral	15	0.1
69	Cucurbitaceae	***Ecballium elaterium* Rich.**	فقوس الحمير	Fruits, latex	Liver pains, hepatitis, diarrhea, sinusitis, vitiligo, warts	Decoction	Oral	10	0.1
70	Cucurbitaceae	***Lagenaria siceraria* (Molina) Standl.**	سلاوية	Leaves, Fruits, Seeds	Diabetes, hypertension, skin diseases, respiratory infections	Decoction Raw	External use Oral	11	0.1
71	Cupressaceae	***Cupressus sempervirens* L.**	سرو	Leaves, Fruits, Stem	Rheumatism, cough, hemorrhoids, hoarseness, wounds healing	Cataplasm Decoction	External use Oral	10	0.1
72	Cupressaceae	***Juniperus oxycedrus* L.**	عرعار	Leaves, Fruits, Resin	Asthma, flatulence, cough, hair problems, stomach pains, liver pains, bladder ailments, skin diseases, diarrhea	Decoction Maceration Powder	External use Fumigation Mask Oral	51	0.5
73	Ephedraceae	***Ephedra alata spp. alenda* Dec.**	لعلندة	Leaves, Stem	Colds, influenza, appetizer, diabetes, asthma, hypertension, joints inflammations	Decoction	Oral	23	0.2
74	Ericaceae	***Arctostaphylos uva ursi* L.**	عنب الديب	Aerial Part	Urinary tract purifier, incontinence, vaginal infections, Gastrointestinal disorders, diarrhea, diabetes, hypertension, cardiac ailments, appetizer, stomach pains	Decoction	Oral	15	0.1
75	Euphorbiaceae	***Euphorbia guyoniana* Boiss. & Reut.**	لعماية	Aerial Part	Insect bites and stings, warts, acne, eczema	Cataplasm	External use	14	0.1
76	Euphorbiaceae	***Rucinus communis* L.**	خروع	Leaves, Seeds	Flatulence, warts, burns, colds, headache, hair problems, scabies, breast tumors	Decoction Oil	External use Mask Oral	30	0.3
77	Euphorbiaceae	***Urtica dioica* L.**	حريقة	Aerial Part	Diabetes, hypotension, oliguria, headache, colds, joints inflammations	Decoction	Oral	11	0.1
78	Fabaceae	***Ceratonia silique* L.**	خروب	Leaves, Fruits, Roots	Diarrhea, vomiting, gastrointestinal disorders, stomach pains, stimulant, warts,	Decoction Raw	Oral Mouth wash	23	0.2

N°	Family name	Botanical name	Vernacular Name	Used Parts	Medicinal Uses	Prep.	Admin.	PRK (%)	IV_s
					gum, and tooth ailments				
79	Fabaceae	***Glycyrrhiza glabra* L.**	عرق السوس	Roots, Stem	Cough, hoarseness, gastrointestinal disorders, flatulence, constipation, ulcers, mouth inflammation, hepatitis	Powder Raw	Mouth wash Oral	15	0.2
80	Fabaceae	***Lens culinaris* Medik.**	لعدس	Entire Plant, Seeds	Liver protective, icterus, skin facial care, anuria, anemia, dental caries, cough, chest pains, gastrointestinal disorders, wounds healing, kidney pains, back pains	Cataplasm Decoction Powder	External use Mask Oral	11	0.1
81	Fabaceae	***Medicago sativa* L.**	فصة	Leaves, Seeds	Diabetes, hemorrhage	Decoction Powder	Oral	10	0.1
82	Fabaceae	***Ononis spinosa* L.**	شديدة	Roots	Urinary infections, kidney stones, wounds healing, eczema	Cataplasm Decoction	External use Oral	10	0.1
83	Fabaceae	***Trigonella foenum-graecum* L.**	حلبة	Seeds	Cancer, sunburn, stimulant, diabetes, galactagogue, gastrointestinal disorders, appetizer, cough, asthma, colds, anemia, hair problems, skin facial care, bruises, oedema, tumors	Cataplasm Decoction Maceration Powder	External use Mask Oral	30	0.3
84	Fabaceae	***Vicia faba* L.**	الفول	Seeds, Leaves	Tuberculosis, gastric burns	Decoction	Oral	13	0.1
85	Fabeaceae	***Acacia nilotica* L.**	سبط	Bark, Leaves	Bronchitis, colds, diabetes, diarrhea	Decoction Powder	Oral	22	0.2
86	Fabeaceae	***Acacia radiana* Savi.**	طلح	Leaves, Gum, Bark, Fruits	Asthma, colic, cough, analgesic, hepatitis, kidney stones, prostate pains, urinary infections, skin diseases	Cataplasm Maceration Powder	External use Oral	47	0.5
87	Fabeaceae	***Retama raetam* Forssk.**	رتم	Aerial Part	Skin diseases, abortifacient, rheumatism, insect bites and stings, wounds healing, oliguria, arrhythmia	Cataplasm Decoction	external use Oral	15	0.1
88	Fagaceae	***Quercus suber* L.**	دباغ	Roots	Gastrointestinal disorders, Hair problems, eczema	Cataplasm Decoction	External use Mask Oral	5	0.1
89	Globulariaceae	***Globularia alypum* L.**	تسلغا، عين الارنب	Leaves, Flowers	Diabetes, laxative, stimulant, antiseptic, constipation, ulcers, wounds healing,	Decoction Infusion	External use Oral	23	0.2

N°	Family name	Botanical name	Vernacular Name	Used Parts	Medicinal Uses	Prep.	Admin.	PRK (%)	IV_s
					abscesses, tumors, bladder diseases				
90	Graminaceae	***Cynodon dactylon* Pers.**	نجم، رجل الغراب	Aerial Part, Rhizome, Roots	Rheumatism, uterus diseases, period pains, kidney stones, stomach pains, bilious troubles, urinary infections, joints inflammations, colds, colic	Decoction	Oral	22	0.2
91	Lamiaceae	***Ajuga iva* L.**	شندقورة	Aerial Part	Antiseptic, anxiety, colds, diabetes, oliguria, earache, fever, female infertility, flatulence, hypotension, insect bites and stings, period pains, migraine, rheumatism, sinusitis, stomach pains, wounds healing	Cataplasm Decoction Powder	Ear drops External use Oral	23	0.2
92	Lamiaceae	***Lavandula dentate* L.**	الخزامة	Entire Plant, Flowers	Hypotension, liver pains, joints inflammations, antiseptic, oliguria, flatulence, headache, stimulant	Decoction	Oral	10	0.1
93	Lamiaceae	***Lavandula stoechas* L.**	حلحال	Leaves, Flowers	Rheumatism, gastrointestinal disorders	Decoction Infusion	Oral	15	0.1
94	Lamiaceae	***Marubium vulgare* L.**	مريوة، التمرصاد	Aerial Part	Bilious troubles, cough, diabetes, mouth inflammation, asthma, colds, gastrointestinal disorders, pulmonary infections, food poisoning, antiseptic, oliguria, weight loss, eczema, earache, fever, wounds healing	Cataplasm Decoction	Ear drops External use Mouth wash Oral	13	0.1
95	Lamiaceae	***Mentha pulegium* L.**	فليو	Stem, Leaves	Bilious troubles, flatulence, sedative, stomach pains, colds, cough, respiratory infections, vomiting, stimulant	Decoction Infusion	Oral	31	0.3
96	Lamiaceae	***Mentha viridis* L.**	نعناع	Stem, Leaves	Flatulence, helminthiasis, diarrhea, colds, headache, gastrointestinal disorders	Decoction Infusion	Oral	22	0.2
97	Lamiaceae	***Ocimum basilicum* L.**	حبق	Leaves, Seeds	Headache, cough, flatulence, colds, rheum, joints inflammations, oliguria, psychosomatic diseases, mouth hygiene, sore throat	Decoction Raw	Mouth wash Oral	31	0.3
98	Lamiaceae	***Rosmarinus officinalis* L.**	لازير	Aerial Part	Flatulence, sedative, oliguria, rheumatism, kidney pains, helminthiasis, bilious troubles, wounds healing, bruises, abscesses, stomach	Cataplasm Decoction Infusion	External use Fumigation Oral	47	0.5

N°	Family name	Botanical name	Vernacular Name	Used Parts	Medicinal Uses	Prep.	Admin.	PRK (%)	IV_s
					pains, period pains, fever, chest pains, uterus diseases.	Powder			
99	Lamiaceae	***Salvia aegyptiaca* L.**	بوفتاش	Aerial Part, Seeds	Colds, female sterility, eyes disorders	Powder	Eye drops Oral	15	0.1
100	Lamiaceae	***Salvia verbenaca* L.**	خياطة	Entire Plant	Wound's healing, appetizer, gastrointestinal disorders, flatulence	Cataplasm Decoction	External use Oral	11	0.1
101	Lamiaceae	***Teucrium polium* L.**	جعدة	Aerial Part	Wound's healing, gastrointestinal disorders, diarrhea, itchy skin	Cataplasm Decoction Infusion	External use Oral	23	0.2
102	Lamiaceae	***Thymus vulgaris* L.**	زعتر	Stem, Leaves	Bronchitis, colds, stomach pains, intestinal pains, cardiac ailments, sedative, period pains, diabetes, respiratory infections	Decoction, Infusion Oil	External use Oral	46	0.5
103	Liliaceae	***Allium cepa* L.**	بصل	Bulbs, Leaves	Asthma, colds, eye disorders, fever, helminthiasis, abscesses, vertigo, earache	Cataplasm Decoction Raw	Ear drops External use Eye drops Oral	23	0.2
104	Liliaceae	***Allium porrum* L.**	كراث	Seeds	Antiseptic, oliguria, colic, nose bleeding, dental caries, cancer, cough, constipation, helminthiasis	Decoction Raw	Oral	15	0.1
105	Liliaceae	***Allium sativum* L.**	ثوم	Bulbs, Stem	Antifungal, food poisoning, colds, colic, cough, eczema, diabetes, headache, helminthiasis, hypotension, Gastrointestinal disorders, migraine, insect bites and stings, sterility, stye, urinary infections, vaginal infections, earache	Cataplasm Decoction Raw	Ear drops External use Oral	15	0.2
106	Liliaceae	***Aloe socotrina* L.**	صبار، مر وصبر	Leaves, Latex	Diabetes, abortifacient, hair problems, eczema	Cataplasm Infusion Powder	External use Oral	31	0.3
107	Liliaceae	***Asphodelus tenuifolius* Cavan.**	تازية	Aerial Part	Anemia, diarrhea, colds, constipation, diabetes, indigestion, measles, rheum, rheumatism, stomach pains, urinary retention, infections, eczema	Decoction Powder	External use Oral	23	0.2

N°	Family name	Botanical name	Vernacular Name	Used Parts	Medicinal Uses	Prep.	Admin.	PRK (%)	IV_s
108	Liliaceae	***Urginea noctiflora* Batt. & Trab.**	بصل الديب	Bulbs	Cancer, fever, sedative, oliguria, helminthiasis, earache, wounds healing, scabies, abscesses, bladder diseases, colds, cardiac ailments, bronchitis, influenza, abortifacient	Cataplasm Infusion	Ear drops External use Oral	14	0.1
109	Linaceae	***Viscum album* L.**	لنجبار	Aerial Part	Bone's cracking, bones care	Cataplasm	External use	10	0.1
110	Lythraceae	***Lawsonia inermis* L.**	حنه	Leaves	Hair problems, antifungal, burns, hypotension, vomiting, gastrointestinal disorders, skin and face care	Cataplasm Decoction	External use Mask Oral	14	0.1
111	Malvaceae	***Gossypium herbaceum* L.**	قطن	Seeds	Gastrointestinal disorders, colds	Decoction	Oral	10	0.1
112	Malvaceae	***Hibiscus esculentus* L.**	ملوخية	Seeds, Fruits	Gastrointestinal disorders, colds	Decoction	Oral	11	0.1
113	Malvaceae	***Malva sylvestris* L.**	لخبيز	Aerial Part, Leaves	Colds, constipation, cough, gastrointestinal disorders, diabetes	Maceration Raw	Oral	23	0.2
114	Moraceae	***Ficus carica* L.**	كرموس، كرمة	Fruits, Latex	Diabetes, laxative, stomach pains, sedative, abscesses, insect bites, and stings	Cataplasm Decoction Raw	External use Oral	11	0.1
115	Moraceae	***Morus nigra* L.**	توت	Fruits, Leaves	Diabetes, laxative, diarrhea, joints inflammations	Decoction Raw	Oral	11	0.1
116	Myrtaceae	***Eucalyptus globulus* Labill.**	كاليبتوس	Leaves, Fruits	Fever, colds, cough, influenza, respiratory infections, hair problems, migraine	Decoction	Mask Oral	31	0.3
117	Oleaceae	***Fraxinus augustifolia* Vahl.**	لسان الطير	Fruits, Leaves	Diabetes, kidney stones, rheumatism, laxative, tuberculosis, oliguria, skin diseases	Decoction Powder	External use Oral	10	0.1
118	Oleaceae	***Olea europea* L.**	زيتون	Fruits, Leaves	Stomach pains, diabetes, helminthiasis, cough, colds, earache	Decoction Infusion Oil Raw	Ear drops Oral	15	0.1
119	Orobanchaceae	***Cistanche tinctoria* (Desf.) Beck.**	دانون	Aerial Part	Diabetes, diarrhea, gastrointestinal disorders, abscesses	Cataplasm Decoction Powder	External use Oral	10	0.1
120	Palmaceae	***Chamaerops humilis* L.**	دوم	Resin	Diabetes, pulmonary infections	Infusion	Oral	5	0.1

N°	Family name	Botanical name	Vernacular Name	Used Parts	Medicinal Uses	Prep.	Admin.	PRK (%)	IV_s
121	Palmaceae	***Phoenix dactylifera* L.**	نخله، بلح، تمر، ذُكّار	Seeds, Fruits, Immature Fruits, Leaves, Male Flowers	Diabetes, expectorant, stimulant, aphrodisiac, diarrhea, fatigue, childhood enuresis, arrhythmia, colds, gum inflammation, vomiting, sterility, sore throat, hemorrhage, hemorrhoids, labor pains	Decoction Powder Raw	Mouth wash Oral	46	0.5
122	Pinaceae	***Pinus halepensis* Mill.**	تايدة	Bark	Stomach pains, diarrhea, tuberculosis, diabetes	Decoction	Oral	11	0.1
123	Pinaceae	***Pinus pinea* L.**	صنوبر	Resin	Ulcers, wounds healing, tooth pains, oliguria, hemorrhoids, tuberculosis	Cataplasm Decoction	External use Mouth wash Oral	12	0.1
124	Plumbaginaceae	***Limoniastrum feei* Batt.**	ملفة الخادم	Aerial Part	Anemia, gastrointestinal disorders, hepatitis, cough	Decoction Powder	Oral	23	0.2
125	Poaceae	***Avena sterilis* L.**	خرطال	Seeds, Roots	Bronchitis, rheumatism, hypercholesterolemia	Powder	Oral	15	0.1
126	Poaceae	***Andropogon nardus* L.**	ليدخير	Aerial Part	Colds, diabetes, liver pains, stomach pains, vaginal infections, rheumatism, prostate pains	Decoction	Oral	31	0.3
127	Poaceae	***Andropogon schoenanthus* Spreng.**	لماد	Aerial Part	Gastrointestinal disorders, rheumatism, joints, and muscular pains, urinary infections, cancer, tooth pains, analgesic, stimulant, oliguria, flatulence	Decoction	Mouth wash Oral	13	0.1
128	Poaceae	***Hordeum vulgare* L.**	الزرع، الشعير	Seeds, Flowers Leaves	Cough, diarrhea, oliguria, laxative, fever, emollient, hypertension, tuberculosis, debility, kidney pains, mouth hygiene, back pains, bladder diseases	Decoction Infusion Powder	Mouth wash Oral	15	0.1
129	Poaceae	***Macrochloa tenacissima* (L.) Kunth.**	حلفا	Leaves, Arial part	Weight loss, colds, flatulence, colic, rheumatism, stomach pains, tooth pains	Decoction Infusion	Mouth wash Oral	23	0.2
130	Poaceae	***Panicum turgidum* Forssk.**	ام الركبة	Aerial Part, Roots	Constipation, skin diseases, scabies, wounds healing	Cataplasm Decoction	External use Oral	10	0.1
131	Poaceae	***Saccharum***	قصب الحلو	Roots	Hair problems	Powder	Mask	5	0.1

N°	Family name	Botanical name	Vernacular Name	Used Parts	Medicinal Uses	Prep.	Admin.	PRK (%)	IV_s
		officinarum **L.**							
132	Poaceae	***Triticum aestivum*** **L.**	القمح	Seeds, Rhizome	Fever, constipation, cough, diarrhea, rheumatism, colic, cancer	Decoction Powder	Oral	14	0.1
133	Poaceae	***Zea mays*** **L.**	ذرة،ماييس	Seeds	Urinary infections, kidney stones, blood pressure, prostate cancer, joints inflammations, weight loss	Decoction	Oral	15	0.1
134	Polygonaceae	***Rumex vesicarius*** **L.**	حميض	Leaves, Roots	Skin diseases, laxative, oliguria, gastrointestinal disorders, tooth pains	Decoction Raw	External use Mouth wash Oral	15	0.2
135	Portulaceae	***Portulaca oleracea*** **L.**	رجلة	Entire Plant, Seeds	Diabetes, fever, emollient, Headache, urinary infections, bladder diseases, helminthiasis, ulcers, hemorrhoids, fever, ophthalmia, diarrhea, skin diseases	Cataplasm Decoction Raw	External use Oral	13	0.1
136	Punicaceae	***Punica granatum*** **L.**	رمان	Pericarps, Leaves	Intestinal antiseptic, stomach pains, diabetes, hoarseness, eczema	Decoction Powder Raw	External use Oral	27	0.3
137	Rananculaceae	***Adonis aestivalis*** **L.**	عين الحجلة	Aerial Part	Cardiotonic, analgesic, hypertension, oliguria	Infusion Powder	Oral	10	0.1
138	Resedaceae	***Randonia Africana*** **Coss.**	قضيم	Fruits	Gastrointestinal disorders, helminthiasis	Raw	Oral	15	0.1
139	Resedaceae	***Reseda villosa*** **Coss.**	ليم	Aerial Part	Food poisoning, sterility, hair problems, skin and face care, sunburn, diarrhea, rheumatism	Cataplasm Decoction	External use Mask Oral	10	0.1
140	Rhamnaceae	***Ziziphus lotus*** **L.**	سدرة، نبق	Fruits, Leaves, Roots	Abscesses, wounds healing, stomach pains, cardiac ailments, pulmonary infections, hemorrhage, colic, diabetes, diarrhea, kidney stones, sore throat, emollient, hair problems	Cataplasm Decoction Powder Raw	External use Mask Oral	48	0.5
141	Rosaceae	***Cydonia oblonga*** **Mill.**	سفرجل	Entire Plant	Phthisis, hepatitis, vomiting, hemorrhoids, diarrhea, cancer, cough, enteritis, rheum	Decoction Raw	Oral	10	0.1
142	Rosaceae	***Malus communis*** **Desf.**	تفاح	Fruits	Anemia, helminthiasis, wounds healing, rheumatism, fever, bilious troubles, diarrhea, pulmonary infections, liver pains	Cataplasm Raw	External use Oral	13	0.1

N°	Family name	Botanical name	Vernacular Name	Used Parts	Medicinal Uses	Prep.	Admin.	PRK (%)	IV_s
143	Rosaceae	***Neurada procumbens* L.**	سعدان	Aerial part	Stimulant	Decoction	Oral	6	0.1
144	Rosaceae	***Prunus dulcis* Mill.**	لوز المر	Seeds	Skin and face care, eczema, hair problems, diabetes	Cataplasm Decoction Powder	External use Mask Oral	15	0.1
145	Rosaceae	***Prunus persica* (L.) Batsch**	خوخ	Fruits, Leaves	Insect bites and stings, liver swelling, cancer	Decoction Powder Raw	External use Oral	23	0.2
146	Rosaceae	***Pyrus communis* L.**	الاجاص، بوعويدة	Fruits, Leaves	Sedative, fever, wounds healing	Cataplasm Raw	External use Oral	10	0.1
147	Rutaceae	***Citrus limon* Burm.**	ليم، الحامض، ليمون	Fruits, Pericarps Leaves	Antiseptic, diarrhea, skin facial care, fever, headache, hypotension, cough, kidney pains, vomiting, appetizer, eczema, cholera, scurvy, rheumatism, malaria, helminthiasis, fatigue	Decoction Raw	External use Oral	14	0.1
148	Rutaceae	***Citrus vulgaris* Risso.**	تشين، البرتقال	Fruits, Pericarps	Analgesic, sedative, appetizer, fever, headache, gastrointestinal disorders, vomiting, nervous disorders, laxative, migraine, insect bites and stings, labor pains	Decoction Raw	External use Oral	14	0.1
149	Rutaceae	***Ruta chalepensis* L.**	فيجل	Aerial Part	Abortifacient, rheumatism, gastrointestinal disorders, sterility, helminthiasis, epilepsy, fever, vitiligo, diabetes, constipation, mouth hygiene	Decoction Powder	Fumigation Mouth wash Oral	23	0.2
150	Salicaceae	***Salix fragilis* L.**	صفصاف	Leaves, Bark	Burns, scabies, oedema, oliguria, fever, gum inflammation	Cataplasm Decoction	External use Mouth wash Oral	10	0.1
151	Salsolaceae	***Suadela fructicasa* L.**	شرياط	Aerial Part	Rheumatism	Cataplasm	External use	10	0.1
152	Solanaceae	***Datura stramonium* L.**	شدق الجمل	Seeds, Leaves	Asthma, sedative, hallucinate	Decoction	Oral	6	0.1
153	Solanaceae	***Hyoscyamus muticus* L. (Coss.) Maire.**	بتيمة، هبالة	Leaves	Back pains, joints and muscular pains, eye disorders, lice, anxiety	Decoction Powder	External use Eye drops	10	0.1
154	Solanaceae	***Lycopersicon***	طماطم	Fruits	Renal and urinary infections, bones	Cataplasm	External use	11	0.1

N°	Family name	Botanical name	Vernacular Name	Used Parts	Medicinal Uses	Prep.	Admin.	PRK (%)	IVs
		***esculentum* Mill.**			cracking, rheumatism, Scurvy, kidney stones, oliguria, skin facial care	Decoction Raw	Mask Oral		
155	Solanaceae	***Solanum tuberosum* L.**	بطاطا	Leaves, Fruits	Burns, Bronchitis, Respiratory infections	Cataplasm Decoction	External use Oral	11	0.1
156	Tamaricaceae	***Tamarix aphylla* (L.) Karst.**	الاثل، الثلاية	Aerial Part	Fever, period pains, lice	Decoction	Oral	11	0.1
157	Tamaricaceae	***Tamarix gallica* L.**	فرسيق	Aerial Part	Allergy, Rheumatism, colds, diarrhea, wounds healing, hemorrhoids, hair problems	Cataplasm Decoction	External use Mask Oral	22	0.2
158	Thymeleaceae	***Thymelea microphylla* Coss.**	متنان	Aerial Part	Rheumatism, colds, back pains, migraine, diabetes, Abscesses, stomach pains, earache, hair problems	Cataplasm Decoction	Ear drops External use Mask, Oral	22	0.2
159	Viticaceae	***Vitis vinifera* L.**	عنب، الدالية	Fruits, Leaves	Fatigue, gastrointestinal disorders, cough, expectorant, stimulant	Decoction Raw	Oral	11	0.1
160	Zygophyllaceae	***Nitraria retusa* (Forsk.) Asch.**	قرزيم، القطف الحلو	Leaves, Fruits	Wounds healing, tumors, eczema, cancer, hypocholesterolemia	Decoction Powder	External use Oral	46	0.5
161	Zygophyllaceae	***Peganum harmala* L.**	حرمل	Leaves, Seeds	Allergy, Headaches, Rheumatism, back pains, fever, colds, diabetes, period pains, anxiety hallucinate, helminthiasis, sterility, uterus diseases, abortifacient, ulcers, hair problems, eczema, tumors	Cataplasm Decoction Maceration Powder	External use Mask Oral	32	0.3
162	Zygophyllaceae	***Zygophyllum album* L.**	عقاية	Leaves	Liver diseases, helminthiasis, diabetes, diarrhea, rheumatism, eczema, analgesic, antiseptic, abscesses	Cataplasm Decoction Infusion, Powder	External use Oral	31	0.3

The percentage of respondents who have knowledge (PRK) regarding the use of a species (frequency of citation) in the treatment of diseases was estimated. The most-reported plants in the current study are *Artemisia herba alba* Asso. (57%), *Juniperus oxycedrus* L., *Hammada scoparia* Pomel. (51% each), *Atriplex halimus* L., *Cotula cinerea* Del. (49% each), *Ziziphus lotus* L. (48%), *Acacia radiana* Savi., *Ràsmarinus officinalis* L. (47%), *Nitraria retusa* (Forsk.) Asch., *Phoenix dactylifera* L., *Thymus vulgaris* L. (46% each). High PRK indicates high use reports for a plant implying its relative importance to the local community for health care needs.

Table III.3. Percentage of Respondents Who Have Knowledge (PRK)

Family name	Botanical name	Vernacular name	PRK (%)
Asteraceae	*Artemisia herba alba* Asso.	شيح	57
Chenopodiaceae	*Hammada scoparia* Pomel.	رمث	51
Cupressaceae	*Juniperus oxycedrus* L.	عرعار	51
Chenopodiaceae	*Atriplex halimus* L.	قطف، القطف المالح	49
Asteraceae	*Cotula cinerea* Del.	قرطوفة البيضا	49
Rhamnaceae	*Ziziphus lotus* L.	سدرة، نبق	48
Fabeaceae	*Acacia radiana* Savi.	طلح	47
Lamiaceae	*Rosmarinus officinalis* L.	لازير	47
Zygophyllaceae	*Nitraria retusa* (Forsk.) Asch.	قرزيم، القطف الحلو	46
Palmaceae	*Phoenix dactylifera* L.	نخلة، بلح، تمر، ذُكّار	46
Lamiaceae	*Thymus vulgaris* L.	زعتر	46
Asteraceae	*Anvillea Radiata* Coss. & Dur.	نقد	32
Cucurbitaceae	*Citrullus colocynthis* Schrad.	حدج، حنظل	32
Apiaceae	*Foeniculum vulgare* Mill.	نافع، بسباس	32
Zygophyllaceae	*Peganum harmala* L.	حرمل	32
Liliaceae	*Aloe socotrina* L.	صبار، مر وصبر	31
Apiaceae	*Ammodaucus leucotrichus* Coss. & Dur.	نسوفة، مو دريقة	31
Chenopodiaceae	*Anabasis aretioides* Bunge.	دقع، صلاء	31
Asteraceae	*Artemisia arborescens* L.	شيبة	31
Asteraceae	*Bubonium graveolens* Forsk.	طفس	31
Capparaceae	*Capparis spinosa* L.	كبار، كبار سيد الشيخ	31
Chenopodiaceae	*Chenopodium ambrosioides* L.	مخينزة	31
Poaceae	*Cymbopogon nardus* L.	ليدخير	31
Myrtaceae	*Eucalyptus globulus* Labill.	كاليبتوس	31
Asteraceae	*Launeae arboresens* (Batt.) Murb.	ام لبينة	31
Asteraceae	*Matricaria pubescens* (Desf.) Schultz.	وزوازة	31
Lamiaceae	*Mentha pulegium* L.	فليو	31
Lamiaceae	*Ocimum basilicum* L.	حبق	31
Zygophyllaceae	*Zygophyllum album* L.	عقاية	31
Euphorbiaceae	*Rucinus communis* L.	خروع	30
Fabaceae	*Trigonella foenum-graecum* L.	حلبة	30

In this study, The Importance Value (IVs) of the cited plants ranges from 0.1-0.6. The highest IVs calculated here is 0.6 which has been recorded for the plant *Artemisia herba alba* Asso., and 0.5 which has been recorded for ten plants: *Juniperus oxycedrus* L., *Hammada scoparia* Pomel., *Atriplex halimus* L., *Cotula cinerea* Del., *Ziziphus lotus* L., *Acacia radiana* Savi., *Rosmarinus officinalis* L., *Nitraria retusa* (Forsk.) Asch., *Phoenix dactylifera* L., *Thymus vulgaris* L. The highest score for the Importance Value of these plants highlights that these plants are therapeutically very important and the interviewed healers in the area rely mostly upon them for effective treatment.

Table III.4. Importance Value (IVs) of Most Reported Plants

Family Name	Botanical Name	Vernacular Name	IV_s
Asteraceae	*Artemisia herba alba* Asso.	شيح	0.6
Fabeaceae	*Acacia radiana* Savi.	طلح	0.5
Chenopodiaceae	*Atriplex halimus* L.	قطف، القطف المالح	0.5
Asteraceae	*Cotula cinerea* Del.	قرطوفة البيضا	0.5
Chenopodiaceae	*Hammada scoparia* Pomel.	رمث	0.5
Cupressaceae	*Juniperus oxycedrus* L.	عرعار	0.5
Zygophyllaceae	*Nitraria retusa* (Forsk.) Asch.	قرزيم، القطف الحلو	0.5
Palmaceae	*Phoenix dactylifera* L.	نخله، بلح، تمر، ذُكّار	0.5
Lamiaceae	*Rosmarinus officinalis* L.	لازير	0.5
Lamiaceae	*Thymus vulgaris* L.	زعتر	0.5
Rhamnaceae	*Ziziphus lotus* L.	سدرة، نبق	0.5
Liliaceae	*Aloe socotrina* L.	صبار، مر وصبر	0.3
Apiaceae	*Ammodaucus leucotrichus* Coss. Dur.	نسوفة، مو دريقة	0.3
Chenopodiaceae	*Anabasis aretioides* Bunge.	دقع، صلاع	0.3
Asteraceae	*Anvillea Radiata* Coss. Dur.	نقد	0.3
Asteraceae	*Artemisia arborescens* L.	شيبة	0.3
Asteraceae	*Bubonium graveolens* Forsk.	طفس	0.3
Capparaceae	*Capparis spinosa* L.	كبار، كبار سيد الشيخ	0.3
Chenopodiaceae	*Chenopodium ambrosioides* L.	مخينزة	0.3
Cucurbitaceae	*Citrullus colocynthis* Schrad.	حدج، حنظل	0.3
Poaceae	*Cymbopogon nardus* L.	ليدخير	0.3
Myrtaceae	*Eucalyptus globulus* Labill.	كاليبتوس	0.3
Apiaceae	*Foeniculum vulgare* Mill.	نافع، بسباس	0.3
Asteraceae	*Launeae arboresens* (Batt.) Murb.	ام لبينة	0.3
Asteraceae	*Matricaria pubescens* (Desf.) Schultz.	وزوازة	0.3
Lamiaceae	*Mentha pulegium* L.	فليو	0.3
Lamiaceae	*Ocimum basilicum* L.	حبق	0.3
Zygophyllaceae	*Peganum harmala* L.	حرمل	0.3
Punicaceae	*Punica granatum* L.	رمان	0.3
Euphorbiaceae	*Rucinus communis* L.	خروع	0.3
Fabaceae	*Trigonella foenum-graecum* L.	حلبة	0.3
Zygophyllaceae	*Zygophyllum album* L.	عقاية	0.3

A total of 162 plants were used for curing more than 99 aliments. The majority of plant species had more than a single therapeutic use. According to the survey, the population of the Bechar region use plants to treat various diseases such as Diabetes (57 spp., 35%), colds (50 spp., 31%), gastrointestinal disorders (44 spp., 27%), stomach pains, and rheumatism (42 spp., 26% each), vertigo (41 spp., 25%), diarrhea (32 spp., 20%), gum and tooth ailments (30 spp., 19%) helminthiasis (29 spp., 18%), wounds healing, fever and oliguria (28 spp., 17% each), cancer and tumors, kidney pains (26 spp., 16% each).

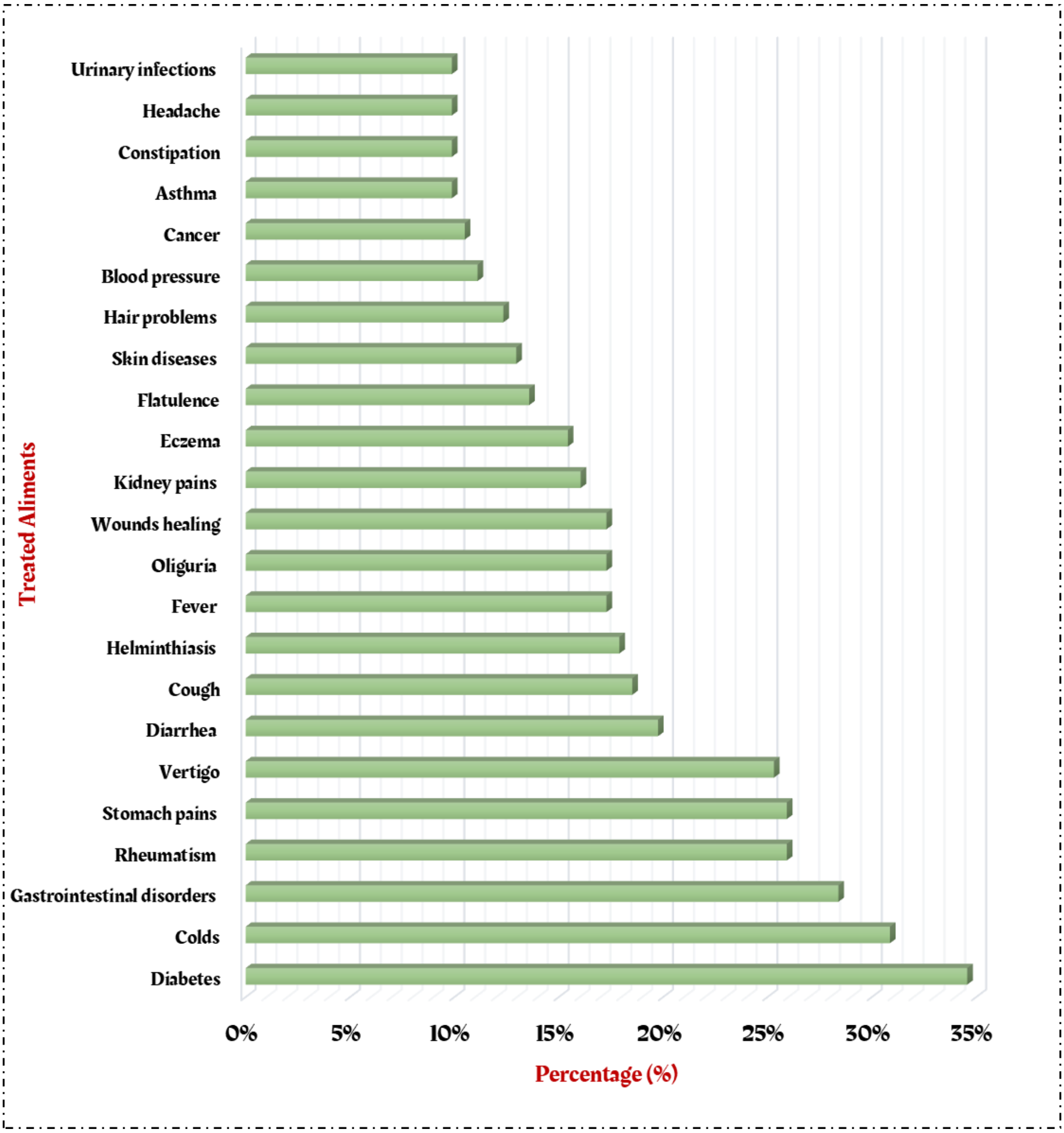


Figure III.12. Most Frequently Treated Disorders

All reported ailments were structured into 11 different pathological groups: cancer and tumors, cardiovascular and circulatory system disorders, dental and oral care, dermatological problems, diabetes, ear, nose, and throat problems, gastrointestinal disorders, genitourinary ailments, respiratory system diseases, rheumatic diseases, skeletomuscular problems.

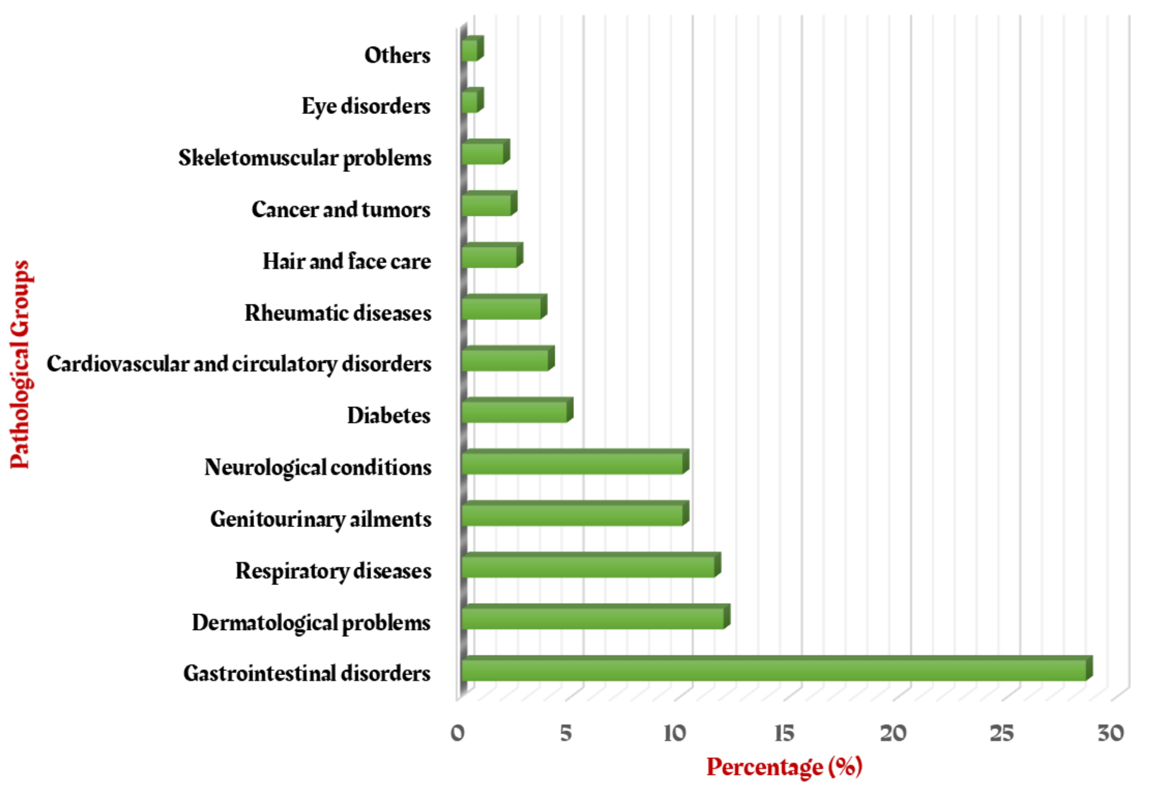


Figure III.13a. Most Frequently Treated Pathological Groups

The pathological groups with the greatest number of records were the gastrointestinal ailments (29%), Dermatological problems (14%), respiratory diseases (12%), Genitourinary ailments and neurological conditions (10% each), Diabetes (5%)., Cardiovascular and circulatory disorders, Rheumatic diseases (4% each) followed by mouth and tooth care (3%), cancer and tumors, ear, nose and throat problems and skeletomuscular problems (4% each). Other diseases were represented by less than 1%. Gastrointestinal disorders were also found to be the most common application of medicinal plants by ethnobotanical surveys carried out in other studies (El-Hilaly et al., 2003; Merzouki et al., 2000; Saadi et al., 2013).

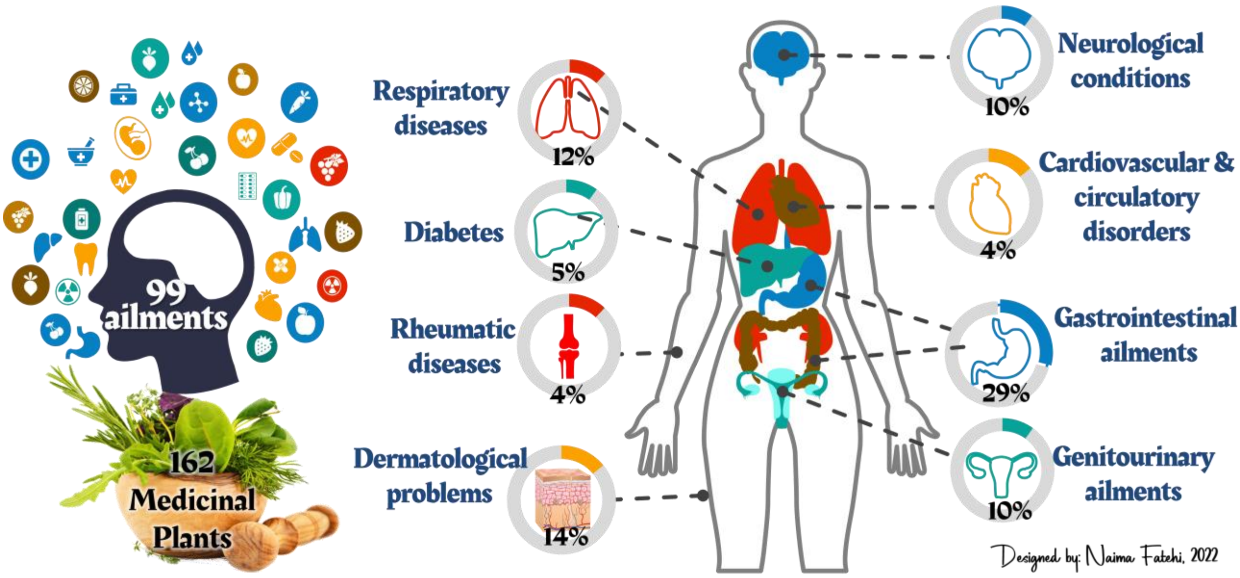


Figure III.13b. Most Frequently Treated Pathological Groups

The Fidelity level is useful for identifying the key informants' most preferred species used for treating certain ailments. The medicinal plants that are widely used by the local people have higher FL values than those that are less popular. Fidelity level shows the percentage of informants claiming the use of a certain plant species for the same major purpose (Ayyanar and Ignacimuthu, 2011; Kassa et al., 2020; Ugulu, 2011)**.**

The highest fidelity level value (100%) has been recorded for ten plants such as *Anastatica hierochuntica* L. against female sterility and male impotency, *Artemisia herba alba* Asso. against gastrointestinal disorders, *Herniaria glabra* L. against kidney stones, *Moricandia arvensis* (L.) DC. against syphilis, *Peganum harmala* L. against uterus diseases, *Phoenix dactylifera* L. against sterility, *Randonia Africana* Coss. against helminthiasis, *Salvia aegyptiaca* L. against eyes disorders, *Salvia verbenaca* L. for wounds healing, and *Zygophyllum album* L. against diabetes.

Table III.5. Medicinal Plants with a High Fidelity Level (FL> 80%)

Medicinal Plant	Vernacular Name	Medicinal Use	FL (%)
Anastatica hierochuntica L.	كف مريم، كمشة	Female sterility and male impotency	100
Artemisia herba alba Asso.	شيح	Gastrointestinal disorders	100
Herniaria glabra L.	فتات الحجر	Kidney stones	100
Moricandia arvensis (L.) DC.	كرم الجمل	Syphilis	100
Peganum harmala L.	حرمل	Uterus diseases	100
Phoenix dactylifera L.	نخلة، ذكار	Sterility	100
Randonia Africana Coss.	قضيم	Helminthiasis	100
Salvia aegyptiaca L.	بوفتاش	Eyes disorders	100
Salvia verbenaca L.	خياطة	Wound's healing	100
Zygophyllum album L.	عقاية	Diabetes	100
Atriplex halimus L.	قطف، قطف المالح	Cancer and tumors	96
Citrullus colocynthis Schrad.	حدج، حنظل	Rheumatism	96
Nitraria retusa (Forsk.) Asch.	قرزيم، قطف الحلو	Cancer and tumors	95
Hammada scoparia Pomel.	الرمث، الرمث الاخضر	Wound's healing and insect bites & stings	92
Ammodaucus leucotrichus Coss. & Dur.	نسوفة، مودريقة	Hypotension	91
Mentha viridis L.	نعناع	Flatulence	91
Traganum nudatum Del.	ضمران	Cancer	88
Eucalyptus globulus Labill.	كاليبتوس	Respiratory infections	87
Artemisia campestris L.	ألال	Diabetes	85
Foeniculum vulgare Mill.	نافع، بسباس	Flatulence	83
Thymus vulgaris L.	زعتر	Respiratory infections	80

The highest FL% value could be considered as an indicator for the high healing potential of those plants used against the corresponding diseases (Kassa et al., 2020). Plants with highest fidelity level value could also be targeted for the further phytochemical investigation to identify the bioactive compounds that are responsible for their high healing potential.

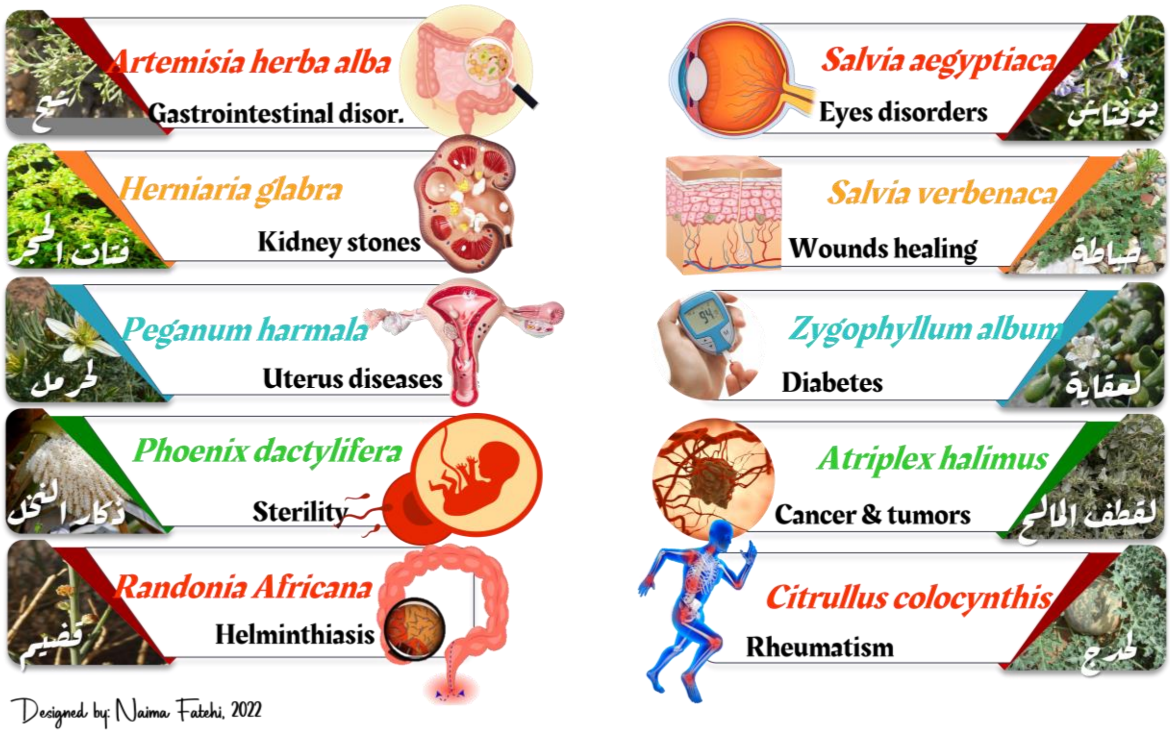


Figure III.14. Medicinal Plants with a High Fidelity Level (FL> 80%)

The importance of the mentioned species in the traditional Algerian pharmacopeia is well known and proved scientifically and various phytochemical investigations on these plants have been undertaken and confirmed their extraordinary medicinal properties (Bezza et al. 2010; Rached et al. 2010; Bouterfas et al. 2014).

Traditionally deemed safe plants can be toxic when they are used on a large scale. Plants may contain powerful chemicals, responsible for side effects and toxicity, their use requires continuous vigilance (Moussaoui et al., 2014). Several toxic plants (used with adequate amounts in traditional medicine) were mentioned in this survey (Table III.6).

The intoxication by these plants is not only related to the fact that they are used in traditional herbal medicine but more especially because of some factors such as overdose, bad methods of use as well as confusion with other edible plants.

Almost all the interviewees did not miss to indicate the toxicity of certain plants, which are used with caution. The survey reveals that 90% of informants have knowledge about the toxicity of plants. The rest said they had no information on toxic plants and the dangers they can cause to health.

Table III.6. Most Frequently Toxic Medicinal Plants Cited

Botanical Name	Vernacular Name	Poisonous Part	Toxic Signs
***Pistacia lentiscus* L.**	ضرو	Leaves, fruits	Constipation, skin irritation
***Ferula asafoetida* L.**	حنطيط	Resin	
***Ferula communis* L.**	كلخ، نرد، الفاسوخ	Stem, resin	Abortion, irritation, death, neurological toxicity
***Thapsia garganica* L.**	درياس، بونافع	Roots, Leaves	Abortion, vomiting, and diarrhea
***Nerium oleander* L.**	دفلة	Whole plant	Death, increased heart rate and irregularity, toxic to eyes, digestive system disorders
***Calotropis procera* Ait.**	كرنكة	Latex, Roots	
***Atractylis gummifera* L.**	أداد	Roots	Vomiting, diarrhea, swilling, death, digestive disorders
Echinops spinosus L.	تسكرة، شوك لحمير	Aerial Part	Abortion
***Launeae arboresens* (Batt.) Murb.**	ام لبينة	Latex	Death
***Woronia saharae* Benth. & Coss.**	كبار المعيز، فسفاس	Leaves, Stem	Nephrotoxicity
***Anastatica hierochuntica* L.**	كف مريم، كمشة	Aerial Part	Neurological disorders, sleep disturbance
***Cannabis sativa* L.**	لكيف	Seeds, Leaves	Ecstasy, hepatotoxicity madness, sedation, neurological toxicity, respiratory problems, dizziness, loss of consciousness, death
***Herniaria glabra* L.**	فتات الحجر	Entire Plant	Hypertension
***Chenopodium ambrosioides* L.**	مخينزة	Leaves, Seeds	Madness, dizziness, death (oral), gallbladder toxicity
***Hammada scoparia* Pomel.**	رمث الاحمر	Entire Plant	Vomiting, abdominal pain, pain general
***Convolvulus althaeoides* L.**	لواية	Leaves, Stem	Death (oral)
***Citrullus colocynthis* Schrad.**	حدج، حنظل	Fruits	Death (high doses), abortion, diarrhea vomiting
***Ecballium elaterium* Rich.**	فقوس الحمير	Fruits, latex	
***Juniperus oxycedrus* L.**	عرعار	Leaves	Neurotoxicity
***Ephedra alata spp. alenda* Dec.**	لعلندة	Aerial Part	Dizziness
***Arctostaphylos uvaursi* L.**	عنب الديب	Aerial Part	Harmful to pregnant women, toxic for people with stomach diseases
***Euphorbia guyoniana* Boiss. & Reut.**	لعماية	Aerial Part	
***Rucinus communis* L.**	خروع	Seeds	Vomiting, eye pain, death, nausea
***Urtica dioica* L.**	حريقة	Aerial Part	skin irritation, allergy, stomachache, skin problems
***Retama raetam* Forssk.**	رتم	Aerial Part	Death (high doses), abortion
***Urginea noctiflora* Batt. & Trab.**	بصل الديب	Bulbs	Diarrhea, death, dizziness, nausea, vomiting
***Viscum album* L.**	لنجبار	Seeds	Constipation, Hepatotoxicity
***Cistanche tinctoria* (Desf.) Beck.**	دانون	Aerial Part	
***Ziziphus lotus* L.**	سدرة، نبق	Roots	Bladder toxicity
***Prunus dulcis* Mill.**	لوز المر	Seeds	Hypotension, fever, death (high doses)
***Ruta chalepensis* L.**	فيجل	Aerial Part	Diarrhea, vomiting, Digestive disorders, nervous disorder
***Suadela fructicasa* L.**	شرياط	Aerial Part	
***Datura stramonium* L.**	شدق الجمل	Seeds	Delirium, madness, hallucination
***Hyoscyamus muticus* L. (Coss.) Maire.**	بتيمة، هبالة	Leaves	
***Peganum harmala* L.**	حرمل	Leaves, Seeds	Hallucinate, Abortion
***Zygophyllum album* L.**	عقاية	Leaves	

In total, 36 medicinal plants belonging to 23 families were here reported to be toxic or present potential toxicity by interviewed people from the study area. These results indicated that they have extensive traditional knowledge of medicinal plants and their harmful effects, and quantitative analyses showed that the inventoried plants may negatively impact different organs and pose a risk to human health. Caution should be exercised when using these plants, particularly for medicinal purposes, and adequate information on these plants including toxicity, composition, and safe doses should be obtained.

In accordance with this, it is suggested that additional studies be conducted to confirm traditional information associated with poisonous plants using appropriate experiments and to determine the identity of toxic phytochemicals associated with poisonous plants.

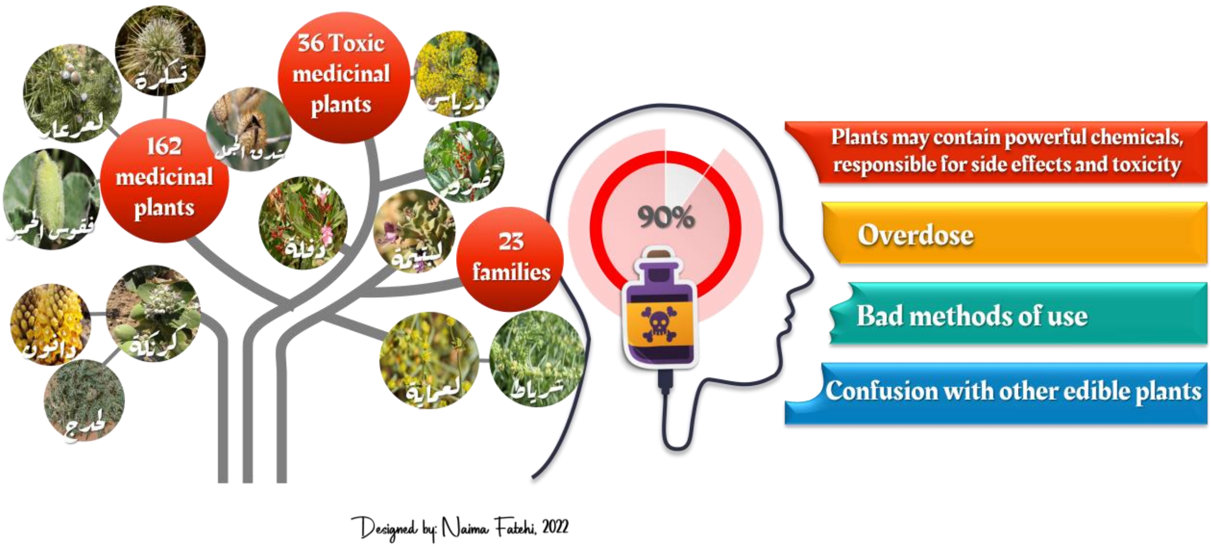


Figure III.15. Most Frequently Toxic Medicinal Plants Cited

II.1. Case Study: COVID-19, Prevention and Treatment with Herbal Medicine

In December 2019, a cluster of pneumonia cases, caused by a newly identified β-coronavirus, occurred in Wuhan, China. This coronavirus was initially named as the 2019-novel coronavirus (2019-nCoV) on 12 January 2020 by World Health Organization. WHO officially named the disease as coronavirus disease 2019 (COVID-19) and Coronavirus Study Group (CSG) of the International Committee proposed to name the new coronavirus as SARS-CoV-2, both issued on 11 February 2020 (Adhikari et al., 2021; Omokhua-Uyi and Van Staden, 2021; Patel et al., 2021).

The current pandemic generates fear in the population who seek solutions to prevent or alleviate the symptoms of the disease since they feel the only resource available to them is self-help, self-care, and self-medicate.

Therefore, it has been reported that some people resource to self-medication, and others to use medicinal plants as potential but unproven methods to ameliorate and/or prevent symptoms related to COVID-19. With the aid of scientists and researchers, there is an urgency to find natural ways to cure this disease. And to make strong anti-COVID-19 herbal medicines from endless plant materials present. Undoubtedly these medicinal plants aid in reducing the patients suffering from illness through the COVID-19 (Adhikari et al., 2021; Omokhua-Uyi and Van Staden, 2021; Patel et al., 2021).

Centered on the fact that COVID-19 is a viral infection, in its prevention and treatment, the use of antiviral medicinal plants may be useful. Given the symptoms of COVID-19 infection, fever, cough, pain in the body, flu, cold and shortness of breath, anti-malarial plants, cough remedies, herbal analgesics and medicinal plants with reasonable therapeutic potentials on infections of the respiratory tract may be useful to prevent COVID-19 infection. So, herbal medicinal plants and their derivatives can be used for the prevention of COVID-19 (Adhikari et al., 2021; Omokhua-Uyi and Van Staden, 2021; Khan et al., 2021; Patel et al., 2021).

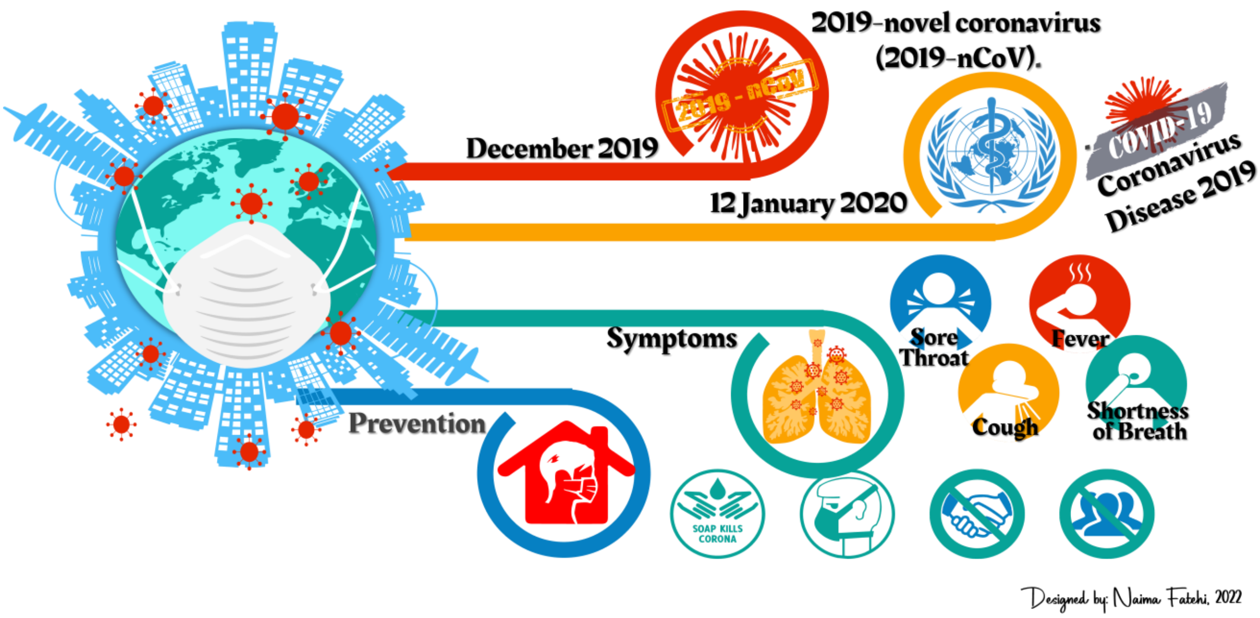


Figure III.16. Case Study: COVID-19 Pandemic

In this section, a separated ethnobotanical survey was conducted to investigate traditional herbalists use of plants for therapeutic purposes in response to the coronavirus pandemic in the Bechar region during 2021.

At the time of the study was conducted (March 21st to November 1st, 2021), the Ministry of Health in Algeria had reported that about 207 000 confirmed COVID-19 cases had been reported nationally. As for the treatment protocol, the Algerian health authorities allowed their hospitals to use the drugs "Hydroxychloroquine", "Azithromycin" "Paracetamol", "Zinc sulfate", and "Vitamin C" to treat the cases with symptoms of the virus.

Since the COVID-19 pandemic outbreak, various traditional herbal medicines have been used and resulted in positive health effects among COVID-19 patients, mainly in the Bechar area. The data obtained from the field and collected from 50 traditional healers, herbalists, and herbal practitioners in different localities of Bechar Province, were well documented from March 21st to November 1st, 2021.

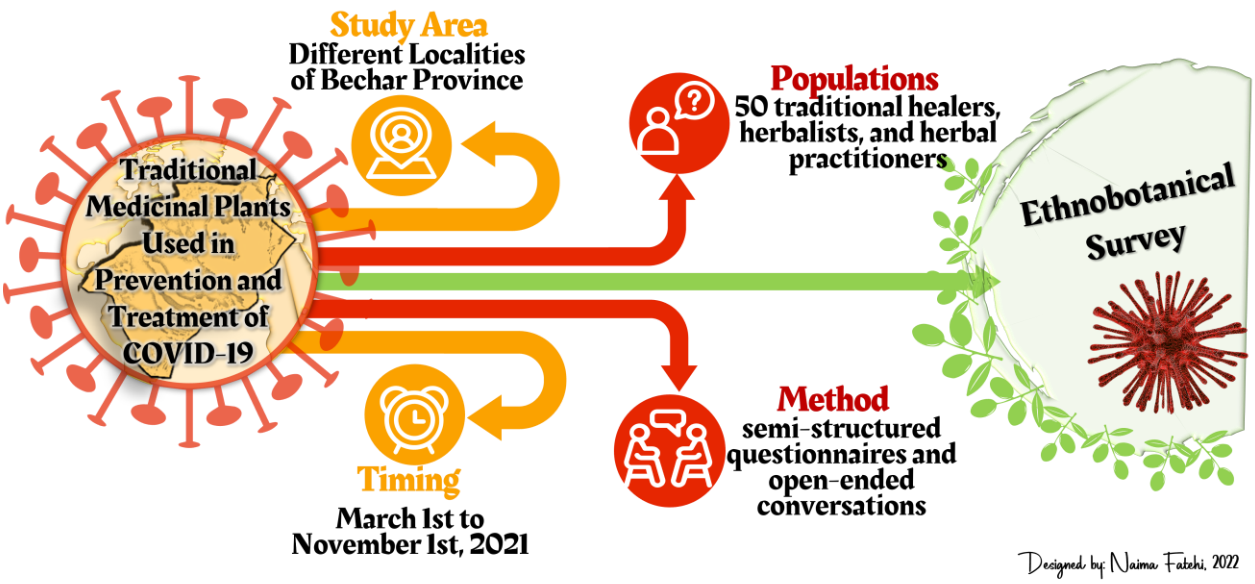


Figure III.17. Ethnobotanical Survey of Medicinal Plants Used in Prevention and Treatment of COVID-19

The present survey showed that a total of 26 plant species belonging to 16 families were frequently used in the prevention and treatment of COVID 19. The vernacular names, scientific names of documented species, their families, mode of preparations, used parts, were illustrated in Table III.7.

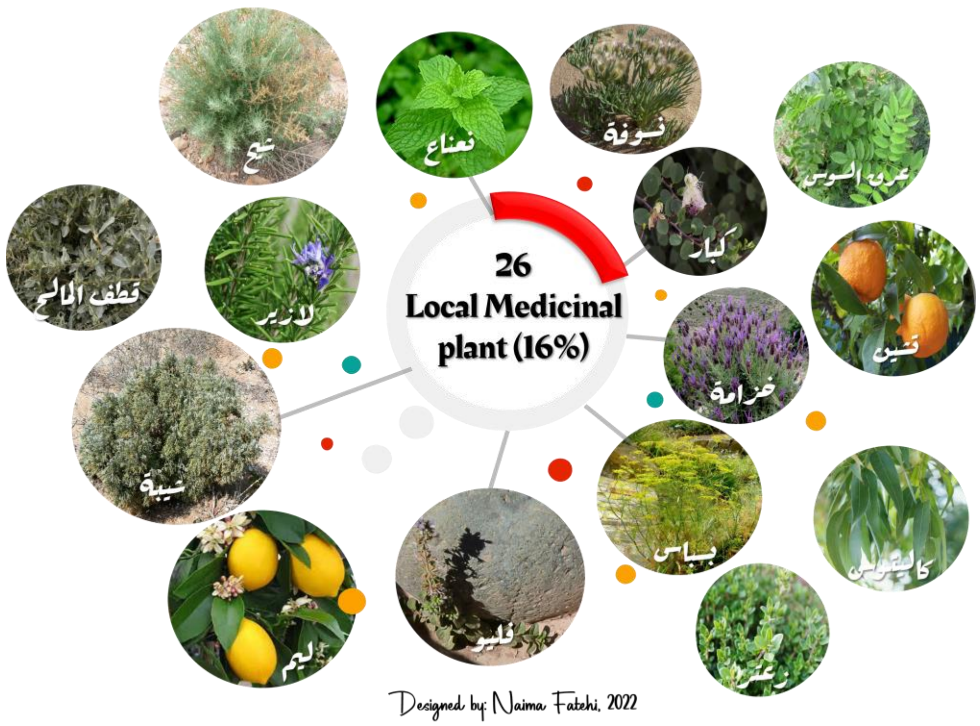


Figure III.18. Most Frequently Used Medicinal Plants in Prevention and Treatment of COVID-19

The family Lamiaceae was represented by the largest number of plant species (5 species, 19%), followed by Apiaceae (4 species, 15%), whereas Asteraceae, Liliaceae, and Rutaceae contributed with two species to each family (8%). The remaining botanical families were represented by one species in each (4%).

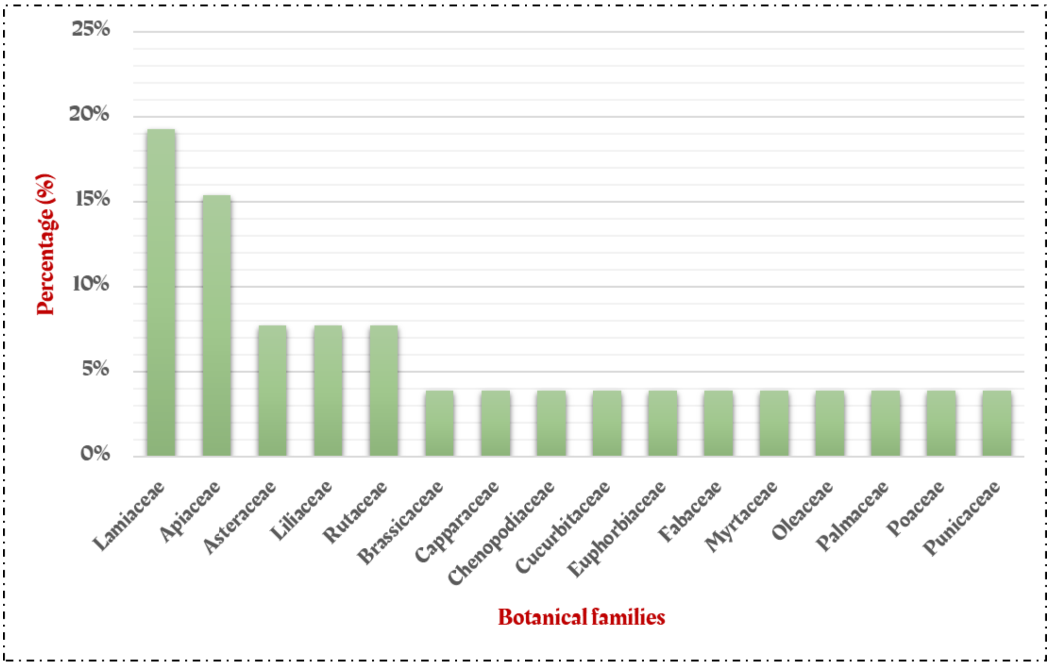


Figure III.19. Cited Botanical Families Used in Prevention and Treatment of COVID-19

The dominance of these families can be explained by their extensive distribution in the study area due to its ecological factors favoring the vegetation of the species belonging to these families. Likewise, these families are widely requested by the local population for the potential of their plant species, especially the Lamiaceae family which includes many aromatic plants.

Furthermore, the ethnobotanical survey carried out in many kinds of research about plants used in the treatment of respiratory diseases recorded that Lamiaceae, Apiaceae, and Asteraceae were the most dominant families (Alami et al., 2020; Hachlafi et al., 2020).

In general, the aerial part has been reported as the most used part by the interviewed herbalists for herbal medicine preparations (32%), followed by fruits (26%), seeds (13%), and leaves (10%). The frequent use of aerial parts is due to the availability, simplicity of harvest, and herbal medicine preparation. Many studies showed that aerial parts, seeds, and leaves were the most used in the treatment of respiratory disorders with slight differences (Hachlafi et al., 2020; Lazli et al., 2019).

Concerning the preparation of herbal medicine, herbalists employ several preparation modes are to facilitate the administration of active principles of medicinal plants. The study showed that Decoction was the dominant preparation method of herbal remedies to fight against COVID-19 (33%), followed by infusion (22%), raw (14%), and fumigation (13.8%). These results are well justified because decoction and infusion are frequently used because they allow collecting the most active compounds of medicinal plants as well as they can attenuate the toxic effect of some recipes (Bouafia et al., 2021; Hachlafi et al., 2020; Salhi et al., 2010).

Table III.7. Medicinal Plants Used to Treat and Prevent COVID-19.

Family Name	Botanical Name	Vernacular Name	Parts Used	Prep.	Admin.
Apiaceae	***Ammodaucus leucotrichus* Coss. & Dur.**	نسوفة، مو دريقة	Fruits, Seeds	Decoction, Infusion, Raw	Oral
Apiaceae	***Apium graveolens* L.**	كرافس	Aerial Part	Decoction Cooked	Oral
Apiaceae	***Foeniculum vulgare* Mill.**	نافع، بسباس	Seeds	Decoction, Infusion, Raw	Oral
Apiaceae	***Petroselinum crispum* Mill.**	معدنوس	Aerial part	Decoction Raw	Oral
Asteraceae	***Artemisia arborescens* L.**	شيبة	Aerial Part	Decoction Infusion Fumigation	Oral Inhalation
Asteraceae	***Artemisia herba alba* Asso.**	شيح	Aerial Part	Decoction Infusion Fumigation	Oral Inhalation
Brassicaceae	***Brassica oleracea* L.**	اللفت	Fruits	Cooked	Oral
Capparaceae	***Capparis spinosa* L.**	كبار، كبار سيد الشيخ	Leaves	Decoction Infusion	Oral
Chenopodiaceae	***Atriplex halimus* L.**	قطف، القطف المالح	Leaves	Decoction	Oral
Cucurbitaceae	***Cucurbita pepo* L.**	لكابوية، القرعة	Seeds, Fruits	Cooked	Oral
Euphorbiaceae	***Urtica dioica* L.**	حريقة	Aerial Part	Decoction Infusion	Oral
Fabaceae	***Glycyrrhiza glabra* L.**	عرق السوس	Stem	Decoction Infusion, Raw	Oral
Lamiaceae	***Lavandula dentate* L.**	الخزامة	Aerial Part	Decoction Infusion Fumigation	Oral Inhalation
Lamiaceae	***Mentha pulegium* L.**	فليو	Aerial Part	Decoction Infusion Essential oil	Oral Inhalation
Lamiaceae	***Mentha viridis* L.**	نعناع	Aerial Part	Decoction Infusion Essential oil	Oral Inhalation
Lamiaceae	***Rosmarinus officinalis* L.**	لازير	Aerial Part	Decoction Infusion Fumigation	Oral Inhalation
Lamiaceae	***Thymus vulgaris* L.**	زعتر	Aerial Part	Decoction Infusion Fumigation	Oral Inhalation
Liliaceae	***Allium cepa* L.**	بصل	Bulbs	Cooked, Raw, Juice	Oral
Liliaceae	***Allium sativum* L.**	ثوم	Bulbs	Raw	Oral
Myrtaceae	***Eucalyptus globulus* Labill.**	كاليبتوس	Leaves	Decoction Infusion	Oral
Oleaceae	***Olea europea* L.**	زيتون	Fruits	Raw Vegetal oil	Oral Massage
Palmaceae	***Phoenix dactylifera* L.**	تمر	Fruits	Powder, Raw	Oral
Poaceae	***Avena sterilis* L.**	خرطال	Seeds	Powder	Oral
Punicaceae	***Punica granatum* L.**	رمان	Pericarps, Fruits	Decoction Juice, Raw	Oral
Rutaceae	***Citrus limon* Burm.**	لم الحامض، ليمون	Fruits, Pericarps	Decoction Juice, Raw	Oral
Rutaceae	***Citrus vulgaris* Risso.**	تشين، البرتقال	Fruits, Pericarps	Decoction Juice, Raw	Oral

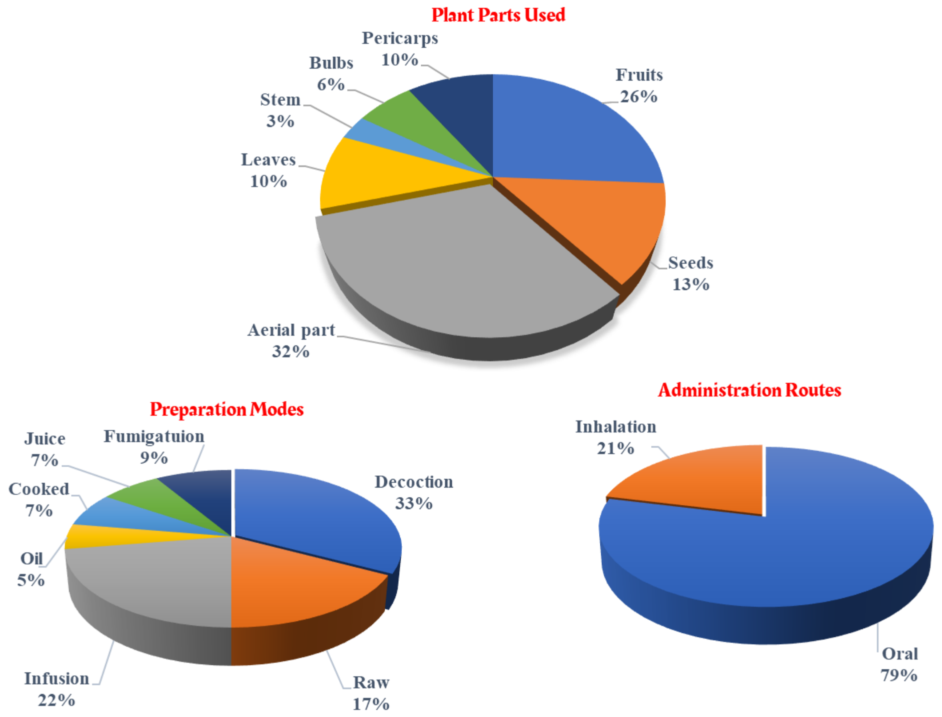


Figure III.20. Frequency of Plant Parts, Preparation Modes, and Administration Routes Used in the Prevention and Treatment of COVID-19.

In our study, data analysis has revealed that most of the remedy preparations are orally prescribed (79%), followed by inhalation (21%). The dominance of oral administration can be explained by the fact that the oral route allows better absorption of active compounds contained in medicinal plants. Our results are consistent with other national and international ethnobotanical surveys reporting that the oral route is the most cited administration mode (Chaachouay et al., 2019; Hachlafi et al., 2020).

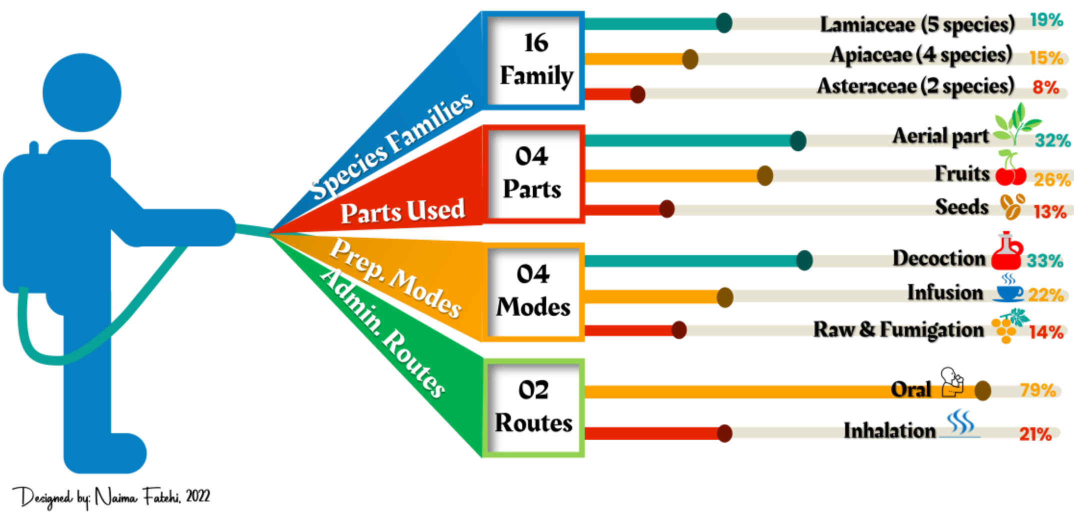


Figure III.21. Results of the Ethnobotanical Survey of Medicinal Plants Used in Prevention and Treatment of COVID-19

The medicinal plants, cited in the survey, contain a wide variety of bioactive compounds including flavonoids (quercetin, kaempferol, hesperetin, eriodictyol, naringenin, and luteolin), alkaloids (pyrrolidine, pyridine, quinoline, isoquinoline, indole, and quinazoline), saponins (escinidin, glycyrrhizin), terpenes (curcumin, betulinic acid, savinin, iguesterin), coumarins (leptodactylone, xanthoangelol E), organosulfur compounds, glycosides, secoiridoid, tannin, mucus, lignans, anthraquinones, aromatic constituents, phenolic lipids, carotenoids, steroids, and many other compounds (Chaachouay et al., 2022, 2020; Oladele et al., 2020; Sytar et al., 2021).

Even though herbal remedies may seem harmless, if misused, they could increase a person's risk for COVID-19. We may find that certain herbs are effective in preventing and treating COVID-19 for some people, however, there currently is not enough data regarding the use of herbal remedies for the novel coronavirus.

The ethnobotanical and ethnopharmacological data demonstrated that medicinal plants play a crucial role in the treatment and prevention of COVID-19 since their use is satisfying the local inhabitants in the study area.

Conclusively, it emerges from this study that the use of traditional medicine based on spontaneous medicinal plants is still very present in the studied region. This work makes it possible to safeguard the practices of phytotherapy which are in danger of extinction due to the oral transmission of these traditions. It can constitute a starting point for other work in the pharmacological and biochemical fields to enhance the floristic richness of the region.

III. Phytochemical Study

Nine plants species, namely, *A. nardus, A. schoenanthus, G. alypum*, two species of *H. scoparia* green & red, *P. laevigata, R. tripartita, T. gallica,* and *T. nudatum*, were collected from different regions of Bechar province.

Complete details of identified plants with botanical name, family, Vernacular name, region, and date of collection are summarized in Table III.8. These plants were chosen based on a survey of the ethnopharmacological populations with knowledge of their use in traditional medicine.

Three of the plant species belong to the Chenopodiaceae family, two of them belong to the Poaceae family, while the rest belong to Anacardiaceae, Asclepiadaceae, Globulariaceae, and Tamaricaceae each.

Table III.8. List of Selected Traditional Medicinal Plants

Scientific Name	Family	Vernacular Name	Region of Collect	Date of Collect
Andropogon nardus **L.**	Poaceae	ليدخير	Bechar	Feb. 2015
Andropogon schoenanthus **L.**	Poaceae	اللماد	Bechar	Mar. 2015
Globularia alypum **L.**	Globulariaceae	تسلغا	Bechar	Mar. 2015
Hammada scoparia **Pomel. Var. red**	Chenopodiaceae	الرمث الأحمر	Bechar	Mar. 2014
Hammada scoparia **Pomel. Var. Green**	Chenopodiaceae	الرمث الاخضر	Lahmer	Mar. 2014
Periploca laevigata **Ait.**	Asclepiadaceae	الحلاب	Bechar	Mar. 2015
Rhus tripartita **R. Sch.**	Anacardiaceae	الجداري	Bechar	Feb. 2015
Tamarix gallica **L.**	Tamaricaceae	فرسيق	Bechar	Mar. 2015
Traganum nudatum **Del.**	Chenopodiaceae	الضمران	Kenadsa	Feb. 2015

III.1. Pre-preparation of Plant Samples

The initial stage in studying medicinal plants is the preparation of plant samples to preserve the biomolecules in the plants before extraction. Plants samples such as leaves, barks, roots, fruits, and flowers can be extracted from fresh or dried plants material. Other pre-preparation of plant materials such as grinding and drying also influences the preservation of phytochemicals in the final extracts (Abubakar and Haque, 2020; Azwanida, 2015). In most cases, the dried sample is preferred considering the time needed for experimental design (Vongsak et al., 2013).

Between grinded and powdered samples, lowering particle size increases surface contact between samples and extraction solvents. Grinding resulted in coarse smaller samples; meanwhile, powdered samples have a more homogenized and smaller particle, leading to better surface contact with extraction solvents (Deli et al., 2019).

III.2. Extraction Procedure

The extraction is the main step for recovering and isolating phytochemicals from plant materials. The initial crude extracts using these methods contain a complex mixture of many plant metabolites, such as alkaloids, glycosides, phenolics, terpenoids, and flavonoids. The extraction efficiency is affected by the chemical nature of phytochemicals, the extraction method used, sample particle size, the solvent used, as well as the presence of interfering substances (Benzarti, 2016; Do et al., 2014; Lourenço et al., 2019; Stalikas, 2007).

III.2.1. Extraction Yield

In this work, all extracts were obtained by using water and aqueous methanol (80%). After extraction and recovering the solvents from the extracts, the dry matters were weighed to determine the yield of each plant.

Extraction yields ranged from 2.44% to 41.64% for aqueous extracts of *A. nardus* and *P. laevigata* respectively (Figure III.22). It can be seen that the extraction yield of aqueous extracts (32.99, 34.40, 41.64, 25.12, 34.58 and 20.61%) is higher than that of hydromethanolic extracts (20.85, 19.59, 31.42, 21.37, 31.15 and 7.76%) for *H. scoparia* green, *H. scoparia* red, *P. laevigata*, *R. tripartita*, *T. gallica*, and *T. nudatum* respectively. It can also be found that the yield of the extracts of *A. schoenanthus* and *G. alypum* is slightly less than each other in both extracts separately, whereas the yield of *A. nardus* hydromethanolic extract (5.25%) is higher than that of its aqueous extract (2.44%).

In this study, the results indicate that the water as a solvent enhances extraction yield more than the methanol aqueous extract (80%). Compounds other than phenolic may have been extracted and contributed to higher yield. This may be attributable to the higher solubility of proteins and carbohydrates in water and aqueous methanol (Tantry et al., 2012; Telichowska et al., 2020).

The yield of extraction depends on the solvent with varying polarity, pH, temperature, extraction time, and composition of the sample (Moyler et al., 1992).

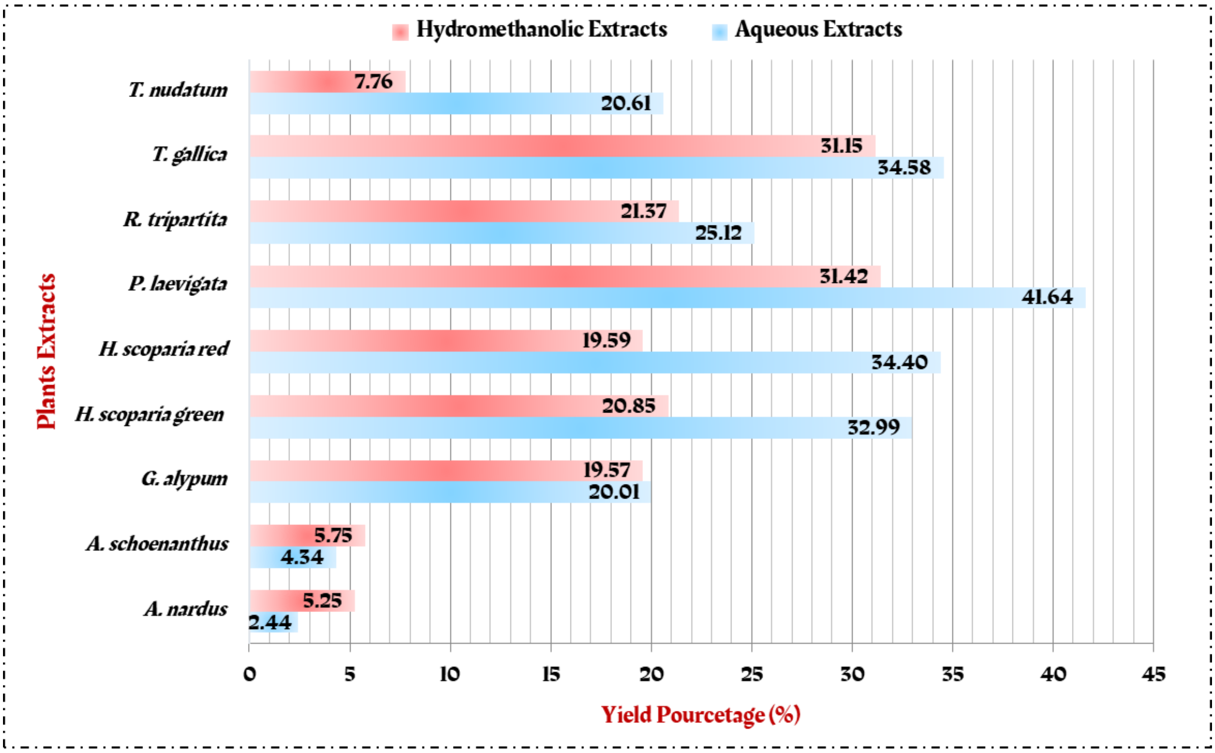


Figure III.22. Total Extraction Yields

In this work, two solvents (water and methanol 80%) were used in the extraction process. They were selected because they can extract compounds with high polarity (Houghton and Raman, 1998).

The polarity of the water molecule makes it a universal solvent. Most cell components including proteins, polysaccharides, and DNA dissolve in water making it the basis of life. While methanol and its different aqueous forms (10-90%, v/v) have been extensively used to extract bioactive compounds from various plants and plant-based foods (fruits, vegetables, etc.) (Sultana et al., 2009).

The combined use of water and organic solvent may facilitate the extraction of chemicals that are soluble in water and/or organic solvent (Cho et al., 2020; Sardarodiyan and Mohamadi Sani, 2016; Telichowska et al., 2020).

III.3. Phytochemical Screening

Phytochemical composition and respective biological activities are important to understand the therapeutic potential of medicinal herbs**.** Most of the studies conclude that pharmacological activities of any medicinal plant are due to the presence of secondary metabolites (Abegaz and Kinfe, 2019; Cahlíková et al., 2020; Gorlenko et al., 2020; Govindan and Shoba, 2015; Jain et al., 2019).

The aqueous and hydromethanolic extracts of the selected plant species were subjected to preliminary qualitative phytochemical screening for the detection of major chemical groups which might be responsible for their medicinal attributes (Table III.9).

Phytochemical study of ***A. nardus*** and ***A. schoenanthus*** showed that all the extracts contained abundantly Alkaloids, Carbohydrates, Flavonoids, Glycosides, Phenols and Quinones, while alkaloids Coumarins and Resins were totally absent.

The phytochemical test results obtained indicated that ***G. alypum*** extracts have almost all the tested phytoconstituents such as Carbohydrates, Flavonoids, Phytosterols Phenols, Quinones, Tannins and Terpenoids. The results also showed that extracts of the two species of ***H. scoparium*** are very rich in many biomolecules like Alkaloids, Flavonoids, Phenols, Quinones, and Tannins. Whereas, some phytoconstituents were totally absent in all the tested extracts such as Carbohydrates, Coumarins, Proteins, and Resins.

The extracts of ***P. laevigata*** and ***R. tripartita*** are rich sources of all the tested compounds namely, Alkaloids, Carbohydrates, Coumarins, Flavonoids, Glycosides, Phytosterols, Proteins, Phenols, Quinones, Tannins, and Terpenoids. Saponins were detected abundantly in the extracts of ***R. tripartita*** but poorly detected in the extracts of ***P. laevigata.*** However, the extracts of ***T. gallica*** are rich sources of Coumarins, Flavonoids, Glycosides, Phytosterols, Proteins, Phenols, and Tannins, whereas alkaloids and Resins were totally absent. ***T. nudatum*** was the poorest plant, almost all the phytoconstituents were poorly detected except for some Flavonoids and Quinones.

The observations and inferences made in the phytochemical tests are presented in the following subsections:

Alkaloids were detected in almost all the extracts except for *T. gallica* and the hydromethanolic extract of *G. alypum*. The most abundant incidence of alkaloids was shown in the extracts of the two species of *H. scoparia* and the hydromethanolic extracts of *P. laevigata* and *R. tripartita*. The rest extracts showed moderate to poor presence of alkaloids. Alkaloids which are one of the largest groups of phytochemicals in plants have amazing effects on humans and this has led to the development of powerful pain killer medications (Adesuyi et al., 2012)**.** Alkaloids may be responsible for the antidiabetics, antiaging and antiviral activities of this herbal plant (Evans and Trease, 2002).

Alkaloids have the biological property of toxicity against cells of foreign organisms. Its activities have been widely studied for their potential use in the elimination and reduction of human cancer cell lines (Narayani et al., 2012; Nobori et al., 1994)**.**

Carbohydrates were detected mainly in the aqueous and hydromethanolic extracts of *P. laevigata* and *R. tripartita*. Carbohydrates were absent in the extracts of the two species of *H. scoparia* and the hydromethanolic extracts of *T. gallica*, where the rest extracts showed moderate to poor presence. Carbohydrates are the most abundant biomolecules in living organisms (Hahm et al., 2016)**.** They are presented as free monosaccharides, oligosaccharides, polysaccharides, and as essential components of glycoconjugates, including glycolipids, glycoproteins, or glycopeptides, and glycosylated natural products. Glycosylated natural products have been commonly used as antimicrobial drugs and now as emerging anti-cancer drug candidates. The sugar moieties in many bioactive natural products do not only increase water solubility thus the bioavailability of the compounds but also decrease toxicity (Tiwari and Mishra, 2011)**.**

Coumarins were observed between moderate to abundant presence in the aqueous and hydromethanolic extracts of *P. laevigata* and *R. tripartita* and the hydromethanolic extract of *T. gallica.* A poor incidence was detected in the aqueous extract of *T. gallica* and the hydromethanolic extracts of *G. alypum* and *T. nudatum*. Whereas, carbohydrates were absent in the extracts of *A. nardus*, *A. schoenanthus*, the two species of *H. scoparia,* and the aqueous extracts of *G. alypum* and *T. nudatum*.

Coumarins are a family of nature-occurring lactones and lactams (Kulkarni et al., 2006). The plant extracts containing coumarin-related heterocycles have been extensively studied for their biological activities. These investigations have revealed their potential as versatile biodynamic agents (Thakor and Savjani, 2014). Coumarins with phenolic hydroxyl groups have the ability to scavenge reactive oxygen species. Recent *in vivo* studies have revealed the role of coumarins in hepatotoxicity, they are undergoing human clinical trials as an orally active anti-tumor drug in view of its farnesyl protein-inhibiting activity in the nanomolar range (Dighe et al., 2010; Roqaiya et al., 2015; Divya Singh et al., 2016)

Flavonoids and related compounds were detected in most samples assayed, mainly in the extracts of the two species of *H. scoparia, P. laevigata, R. tripartita,* and *T. gallica,* and the hydromethanolic extracts of *G. alypum* and *T. nudatum,* while the rest showed moderate to poor presences of flavonoids. Flavonoids may play a role in the prevention of several chronic diseases such as cancer, cardiovascular disease, inflammation, neurodegenerative disorders, and other pathologies associated with oxidative stress (Road, 2017). Epidemiological studies have shown an inverse relationship between the consumption of plant foods rich in flavonoids and the incidence of certain diseases (Cushnie and Lamb, 2005; Tripoli et al., 2005).

Glycosides were observed between moderate to the poor presence in all the aqueous and hydromethanolic extracts of the nine-studied species. Glycosides may be phenol, alcohol, or sulfur compounds. They are characterized by a sugar portion or moiety attached by a special bond to one or non-sugar portions. Most glycosides can be classified as prodrugs since they remain inactive until they are hydrolyzed in the large bowel leading to the release of the aglycone, the right active constituent. Glycosides were reported to exhibit anti-diabetic characteristics (Pengelly, 2004). Cardiac glycosides on the other hand are known to hamper the Na^+/K^+ pump. This increases the level of sodium ions in the myocytes which then enhances the level of calcium ions. This consequently increases the amount of Ca^{+2} ions available for contraction of the heart muscle, which improves cardiac output and reduces distention of the heart and thus is used in the treatment of congestive heart failure and cardiac arrhythmia (Rajalakshmi et al., 2016a).

Out of the nine plants studied, **phytosterols** are abundant in the aqueous and hydromethanolic extracts of *G. alypum* and the hydromethanolic extracts of *H. scoparia* green, *R. tripartita,* and *T. gallica.* Plant steroids are known to be important for their cardiotonic activities, possession of insecticidal, anti-inflammatory, analgesic properties, central nervous system activities, and antimicrobial properties. They are also used in nutrition, herbal medicine, and cosmetics (Rajalakshmi et al., 2016b)**.**

Proteins were detected abundantly only in the two hydromethanolic extracts of *R. tripartita, H. scoparia* green, and *T. gallica*. Proteins were absent in the extracts of *G. alypum*, *T. nudatum,* and aqueous extract of *A. schoenanthus*. A poor incidence was detected in the extracts of *A. nardus, H. scoparia* red, *P. laevigata,* and the rest extracts. Proteins are another class of indispensable biomolecules that make up around 50% of the cellular dry weight. Proteins are polymers of amino acids arranged in the form of polypeptide chains. Proteins play both structural and dynamic roles (Zhang et al., 2015)**.**

Phenols were observed between moderate to abundant presence in the aqueous and hydromethanolic extracts of *A. schoenanthus, G. alypum,* the two species of *H. scoparia, P. laevigata, R. tripartita,* and *T. gallica*, while a poor incidence was detected in the extracts of *A. nardus* and *T. nudatum*. In recent years, interest in plant polyphenols has increased due to their nutraceutical importance. Phenolic compounds are secondary metabolites that synthesize in plants, they are important by their contribution to human health. They possess biological properties such as antioxidant, antiapoptosis, anti-aging, anticarcinogen, anti-inflammation, anti-artherosclerosis, cardiovascular protection, improvement of the endothelial function, as well as inhibition of angiogenesis and cell proliferation activity. Most of these biological actions have been attributed to their intrinsic reducing capabilities (Lin et al., 2016).

Quinones were observed between moderate to the abundant presence in all the aqueous and hydromethanolic extracts except for the extracts of *T. gallica* where a poor incidence was detected. Natural quinones exhibited a biological or pharmacological activity, and some of them showed antitumoral activity. they possess several biological properties, including some claims in herbal medicine. The applications include purgative, anti-microbacterial, anti-tumor, and anti-cardiovascular disease (Mohan Raj et al., 2017)**.**

The abundance of **saponins** were observed in the aqueous extracts of *A. schoenanthus, R. tripartita, T. gallica, T. nudatum,* and the hydromethanolic extracts of *A. nardus.* Whereas, quinones were absent in the aqueous extract of *A. nardus* and the hydromethanolic extracts of *P. laevigata, T. gallica,* and *T. nudatum*. Saponins are glycosides occurring widely in plants. They are abundant in many foods consumed by animals and men. Saponins are used as mild detergents and in intracellular histochemistry staining to allow antibody access to intracellular proteins. In medicine, it is used in hypercholesterolemia, hyperglycemia, antioxidant, anticancer, anti-inflammatory, central nervous system activity weight loss … etc. (Rajalakshmi et al., 2016b)**.** Saponins are also known to have antifungal properties (Berniyanti and Mahmiyah, 2015)**.**

The abundance of **tannins** was observed in the extracts of *R. tripartita, T. gallica,* the aqueous extract of *P. laevigata,* and hydromethanolic extracts of hydromethanolic extract of *H. scoparia* green. Tannins were totally absent in the aqueous extracts of *A. schoenanthus* and *T. nudatum.* Tannins were reported to exhibit antidiabetic (Cushnie and Lamb, 2005), anti-inflammatory, antibacterial and antitumor activities. It has also been reported that certain tannins were able to inhibit HIV replication selectively besides being used as diuretics. Plant tannins have been widely recognized for their pharmacological properties and are known to make trees and shrubs a different meal for many caterpillars (Rajalakshmi et al., 2016b).

On the other hand, **terpenoids** were appreciated in all samples analyzed being particularly abundant in the extracts of *G. alypum, H. scoparia* green, *R. tripartita,* and *T. gallica*. Plant terpenoids played a role in traditional herbal remedies and are under investigation for antibacterial, antineoplastic, and other pharmaceutical functions (Arvind Kumar Shakya, 2016)**.**

Resins were observed abundantly only in two samples: the aqueous extracts of *G. alypum* and *P. laevigata*. A poor incidence was detected in the aqueous extract of *A. schoenanthus*. The term “resin” is often used to describe fragrant plant saps or exudates distinguished from other plant exudates such as gums, mucilages, oils, waxes, and latex. Plant resin is defined primarily as a lipid-soluble mixture of volatile and non-volatile terpenoid, and/or phenolic secondary compounds. Resins usually consist of a volatile fragrant fraction, usually called essential oil, and a non-volatile fraction, usually consisting of long-chain terpenoids. Resins have been used since ancient times as constituents of varnishes, cosmetics, adhesives, and as incense in ritual ceremonies (Dimkić et al., 2016; Gigliarelli et al., 2015).

Phytochemical screening and qualitative estimation of the nine medicinal plants studied showed that the aqueous and hydromethanolic extracts were rich mainly in phenols, flavonoids, alkaloids, tannins, and quinones. The maximum number of phytochemicals were found in the aqueous and hydromethanolic extracts of *R. tripartita* followed by the aqueous extracts of *P. laevigata* and *T. gallica*.

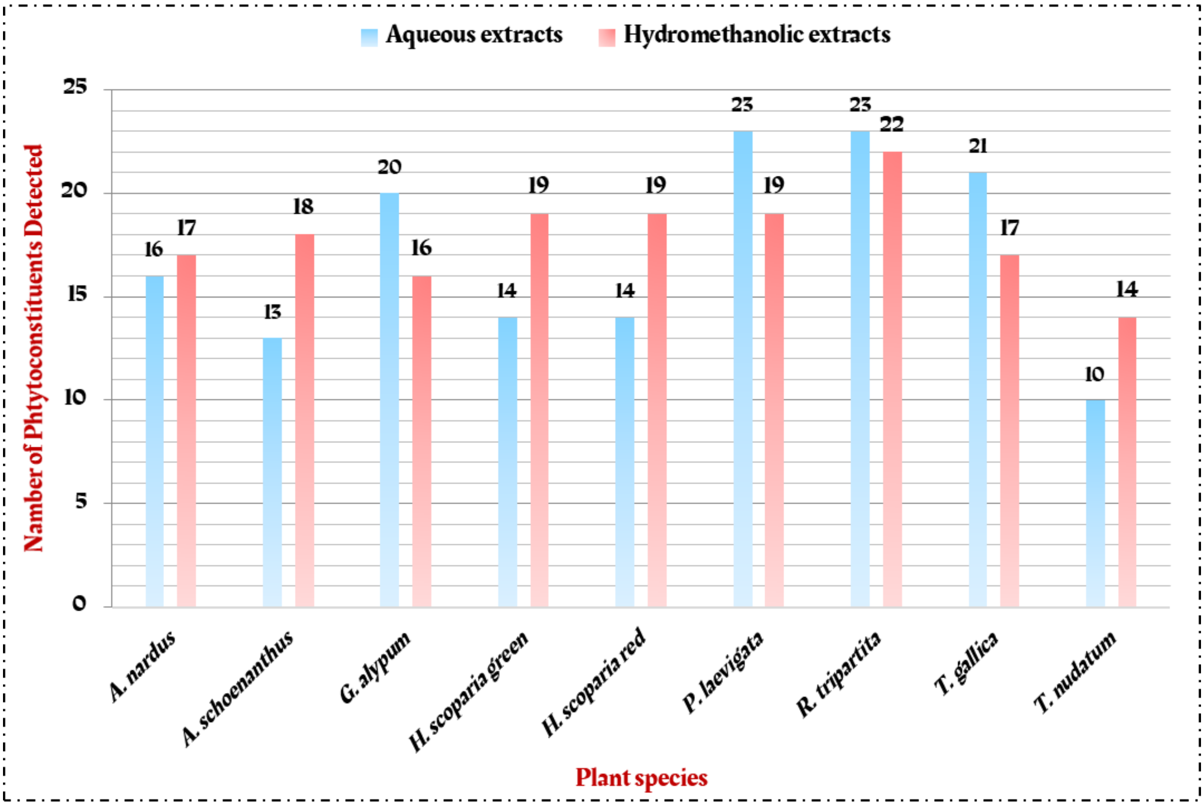


Figure III.23. Number of Phytochemicals in Each Extract

Table III.9. Preliminary Qualitative Phytochemical Analysis

		A. nardus		*A. schoenanthus*		*G. alypum*		*H. scoparia* green		*H. scoparia* red		*P. laevigata*		*R. tripartita*		*T. gallica*		*T. nudatum*	
		A	**HM**	**A**	**HM**	**A**	**HM**	**A**	**HM**	**A**	**HM**	**A**	**HM**	**A**	**HM**	**A**	**HM**	**A**	**HM**
Alkaloids	***Mayer's Test***	+	++	++	+	+	-	+++	+++	+++	+++	++	++	+	+	-	-	+	+
	Wagner's Test	+	+	++	+	+	-	+++	+++	+++	+++	++	+++	++	+++	-	-	-	+
Carbohydrates	***Molisch Test***	++	++	+	+	+	++	-	-	-	+	++	-	+++	++	+	-	++	-
	Fehling's Test	+	+	-	++	++	++	-	-	-	-	+++	+++	+++	+++	++	-	-	++
	Benedict's Test	-	-	-	+	++	++	-	-	-	-	+++	+++	+++	+++	+	-	-	-
Coumarins	***Sodium hydroxide Test***	-	-	-	-	-	+	-	-	-	-	+++	+++	+++	++	+	++	-	+
Flavonoids	***Lead acetate Test***	++	++	+	+	+	-	+	+++	++	+++	+++	+	+++	++	++	++	+	+
	Shinoda Test	-	+	+	+	+	-	+	+++	++	+++	+++	+	+++	++	++	++	+	+
	Ammoniac Test	++	++	++	++	++	+++	+++	+++	+++	+++	+++	+++	+++	+++	+++	+++	+	+++
	Zinc Test	-	+	+	-	-	-	+	++	+	++	++	+	++	++	+	++	-	-
Anthocyanin	***Sodium hydroxide Test***	++	-	-	-	-	-	+	-	+	-	+	-	-	++	-	-	-	-
Betacyanin		-	++	++	-	++	+++	-	-	-	+	+	-	+	-	++	++	+	++
Cyanidin aglycones	***Willstätter cyanidin Test***	-	-	-	+++	+++	-	-	+++	-	-	-	-	+	+++	++	+	-	-
Leucoanthocyanins	***Isoamyl alcohol Test***	-	+	-	-	+	++	-	++	-	++	+	-	-	-	-	-	-	-
Glycosides	***Modified Borntrager's Test***	++	+	+	+	+	+	++	++	++	+	++	+	++	+	++	+	+	+
Phytosterols	***Salkowski's Test***	+	-	-	+	+++	++	-	+++	-	+	+	++	++	+++	+	+++	-	-
	Libermann Burchard's Test	+	-	-	++	-	+++	+	++	+	++	++	++	+	++	+	++	-	+
Proteins	***Xanthoproteic Test***	+	+	-	+	+	-	+	++	+	+	+	+	+	++	+++	+	-	-
	Biuret Test	-	-	-	-	-	-	-	+	-	-	-	+	+	+++	+	++	-	-
Phenols	***Ferric Chloride Test***	+	++	++	+++	++	+++	++	++	++	++	+++	+++	+++	-	+++	+++	+	+
Quinones	***Chlorhydric acid Test***	++	+++	+	+++	++	++	+++	+++	++	+++	+++	++	+++	++	+	+	++	+++
Saponins	***Froth Test***	-	+++	+++	+	+	+	+	+	+	+	-	-	+++	++	+++	-	+++	-
Tannins	***Ferric Chloride Test***	+	-	-	++	++	++	+	+++	+	+	+	++	+	+++	+	+	-	+
	Gelatin Test	+	+	-	-	-	+	-	+	-	+	+++	+	+++	+++	+++	+++	-	+
Terpenoids	***Sulfuric acid Test***	+	+	-	+	+++	+++	-	++	-	++	+	++	++	++	+	+	-	-
Resins	***Acetone-water Test***	-	-	+	-	+++	-	-	-	-	-	+++	-	-	-	-	-	-	-

Key: (-) Absence, (+) Poor, (++) Moderate, (+++) Abundant **(A)** Aqueous Extracts, **(HM)** Hydromethanolic Extracts

Every living body, from one cell bacterium to million cell plants, processes diverse chemical compounds for their survival and subsistence. All compounds of the biological system can be divided into two broad arenas. One is primary metabolites, which are the chemical substances aimed at growth and development, such as carbohydrates, amino acids, proteins, and lipids.

Another is secondary metabolites, which are a group of compounds other than primary metabolites believed to help the lants to increase their overall ability to survive and overcome local challenges by allowing them to interact with their surroundings (Harborne, 1993; Sagadevan et al., 2019). These classes of phytochemicals are known to possess a variety of biological activities including antimicrobial, antioxidant, anti-inflammatory, antiplasmodial, and anticancer activities (Dias et al., 2012; Jain et al., 2019).

These findings may partially justify the traditional use of the examined plants in the treatment of many diseases and indicate that they may serve as a source of bioactive compounds against these illnesses (Akter et al., 2016; Le Anh Dao et al., 2020).

III.4. Total Phenolic Contents (TPC)

Plant-derived phenols are of great importance because of their potential antioxidant and antimicrobial properties (Karim et al., 2020; Kumar and Goel, 2019). Folin-Ciocalteu is very sensitive reagent that contains phosphomolybdate and phosphotungstate, which formed blue complex in alkaline solution by the reduction of phenols (Tabasum et al., 2016). Absorbance is measured at 765 nm and phenolic compounds are quantified with the help of a standard curve prepared from pure phenolic standard.

Total phenol compounds, as determined by the Folin Ciocalteu method, are reported as Gallic acid equivalents per gram of dry extract (mg GAE/g) by reference to standard curve ($y = 8.2995x + 0.1085$, $R^2 = 0.9942$).

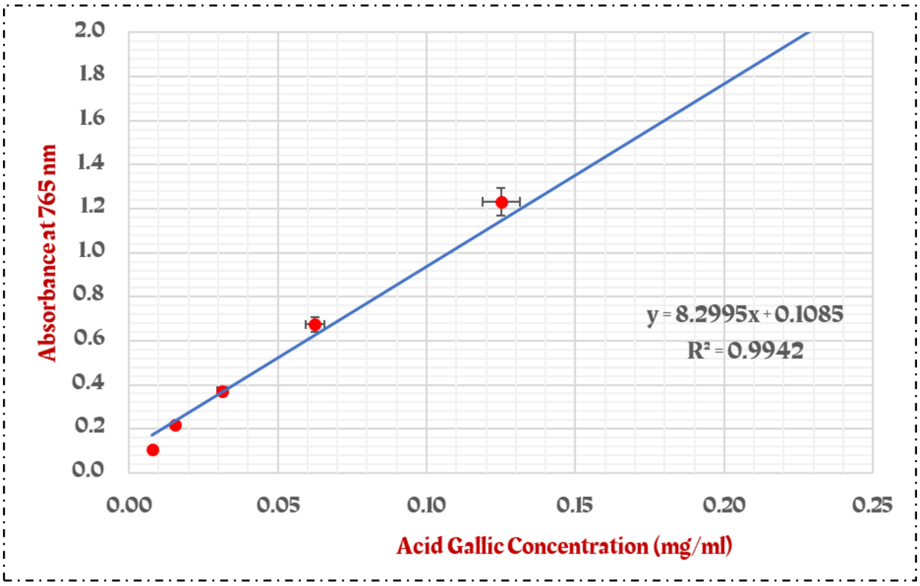


Figure III.24. Acid Gallic Calibration Curve

Results of the assays for phenolics described in the present report indicated a wide variation in the total phenolic content in the different extracts, ranging from 16.848±0.002 to 276.221±0.079 mg GAE/g (Figure III.25). Total phenols content of the hydromethanolic extracts varied from 76.732±0.031 to 245.095±0.037 mg GAE/g while it ranges between 16.848±0.002 and 276.221±0.079 mg GAE/g in aqueous extracts of plant samples. The extracts of *G. alypum*, the two species of *H. scoparia*, *P. laevigata* and *R. tripartita* showed high phenolic value in comparing with the other plant species extracts.

Among all the extracts, aqueous extract of *R. tripartita* (276.221±0.079 mg GAE/g) and hydromethanolic extracts of *P. laevigata* and *H. scoparia* red (245.095±0.037 and 243.609±0.231 mg GAE/g respectively) have the highest phenolic content, followed by the aqueous extract of *H. scoparia* red (222.523±0.168 mg GAE/g) and the hydromethanolic extracts of *G. alypum* and *H. scoparia* green (199.229±0.180 and 190.674±0.004 mg GAE/g respectively).

Furthermore, the aqueous extracts of *A. nardus*, *T. nudatum*, and *A. schoenanthus* obtained the lowest phenolic content (16.848±0.002, 41.790±0.036, and 54.562±0.040 mg GAE/g respectively), followed by the hydromethanolic extracts of *A. nardus*, *T. nudatum*, and *T. gallica* (76.732±0.031, 84.202±0.081 and 90.608±0.063 mg GAE/g respectively).

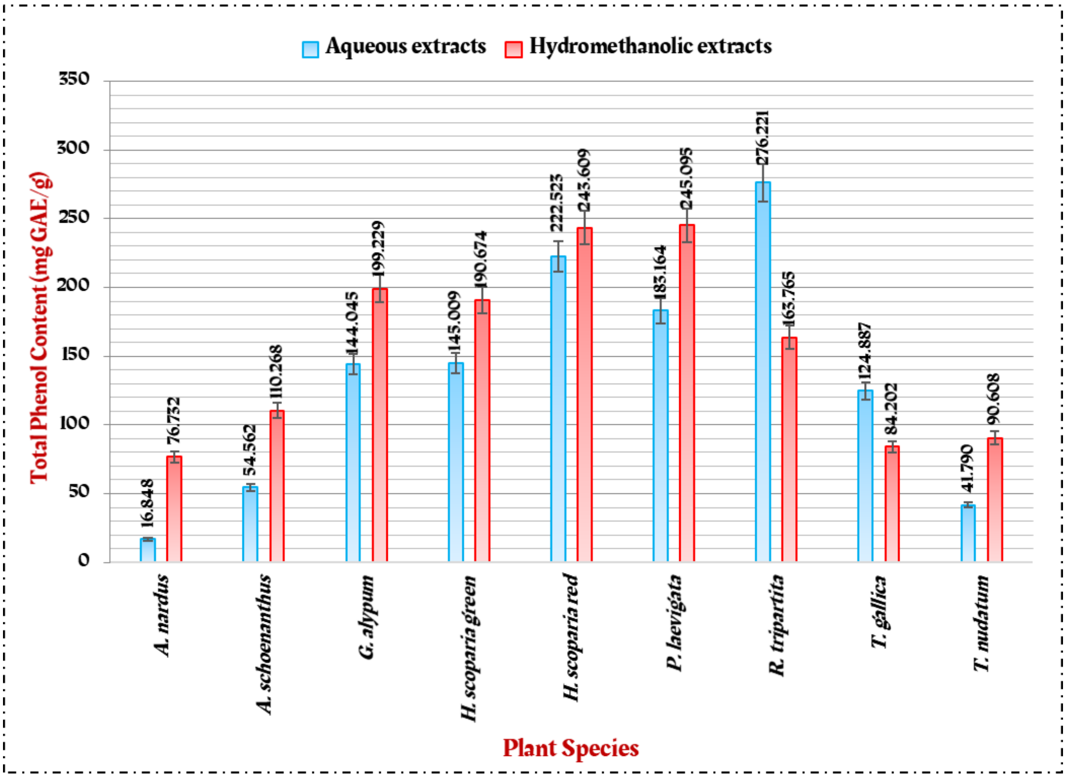


Figure III.25. Total Phenolic Contents of Plant Extracts

Results of these assays demonstrated significant variability in total yield of phenolic compounds. In general, the extractability of a particular component appeared to depend on extraction medium polarity and the ratio of solute to solvent. Moreover, recovery of phenolic compounds appeared dependent on the type of solvent used, its polarity index, and the solubility of phenolic compounds in the extraction solvents (Karim et al., 2020; Lourenço et al., 2019).

The solubility of polyphenols was observed to depend mainly on the presence and position of hydroxyl groups and the molecular size and the length of constituent hydrocarbon chains (Iloki-Assanga et al., 2015)**.** Phenolic compounds are often extracted in higher amounts in more polar solvents. The recovery of phenolic contents in different samples is influenced by the polarity of extracting solvents and the solubility of each compound in the solvent used for the extraction process (Barku et al., 2016)**.** Therefore, it is difficult to select an optimally appropriate solvent for the extraction of phenolics from multiple plant material samples (Dai and Mumper, 2010; Iloki-Assanga et al., 2015; Karim et al., 2020; Lourenço et al., 2019).

III.5. Total Flavonoid Contents (TFC)

Different spectrophotometric methods for the quantification of flavonoids compounds have been developed. Spectrophotometric methods are based on the formation of a compound or colored complex that is measured at a certain wavelength. Some insight into the molecular mechanisms contributing to solvent extraction efficiency may be gained by considering major features of target compounds. For example, the aluminum chloride method involves the formation of stable acid complexes between the $AlCl_3$ reagent and the C-4 keto group; and either the C-3 or C-5 hydroxyl group of flavonoids. In addition, aluminum chloride forms labile acid complexes with the ortho-dihydroxyl groups in the A- or B-ring of flavonoids (Iloki-Assanga et al., 2015).

The total flavonoid contents are reported as mg quercetin equivalent per gram (mg QE /g of dry extract), by reference to standard curve ($y = 1.398x + 0.022$, $R^2 = 0.989$).

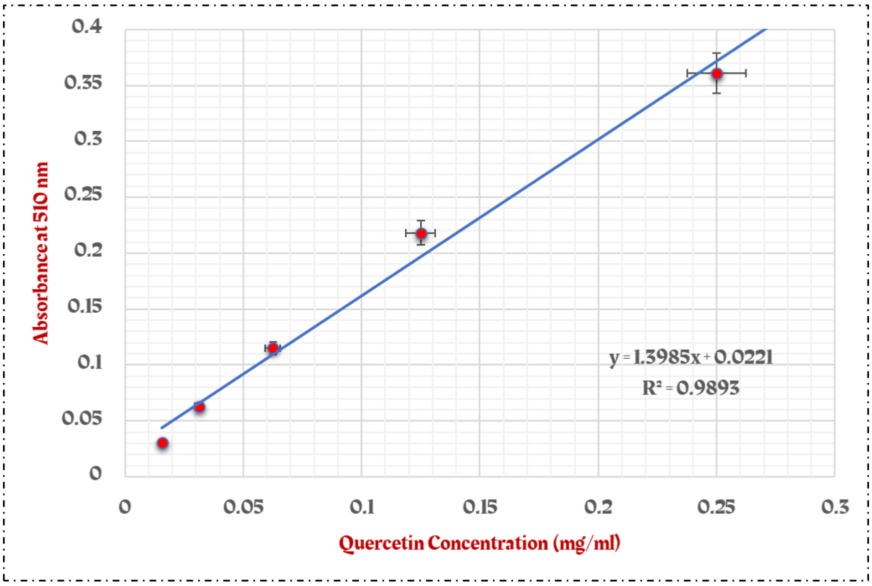


Figure III.26. Quercetin Calibration Curve

Total flavonoids in hydromethanolic extract were placed between 61.531±0.014 and 646.531±0.234 mg QE/g while it ranges between 3.197±0.004 and 341.197±0.084 mg QE/g in water extracts of plant samples (Figure III.27). Among all the extracts, the hydromethanolic extracts of *P. laevigata*, *R. tripartita*, and *G. alypum* have the highest flavonoids content (646.531±0.234, 510.531±0.023, and 494.197±0.077 mg QE/g respectively), followed by the hydromethanolic extracts of *H. scoparia* red and *H.*

scoparia green (371.197±0.067 and 179.197±0.008 mg QE/g). Furthermore, the aqueous extracts of *T. gallica*, *A. nardus*, and *A. schoenanthus* obtained the lowest flavonoid content (3.197±0.004, 5.531±0.007, and 36.864±0.006 mg QE/g respectively).

The hydromethanolic extracts showed the highest amount of flavonoids and aqueous extracts showed the lowest amount. This fact may be due to the low solubility of these compounds in water. Besides, the relation between total phenolic and total flavonoids in plants is a parallel relationship as well as between hydromethanolic and aqueous extracts.

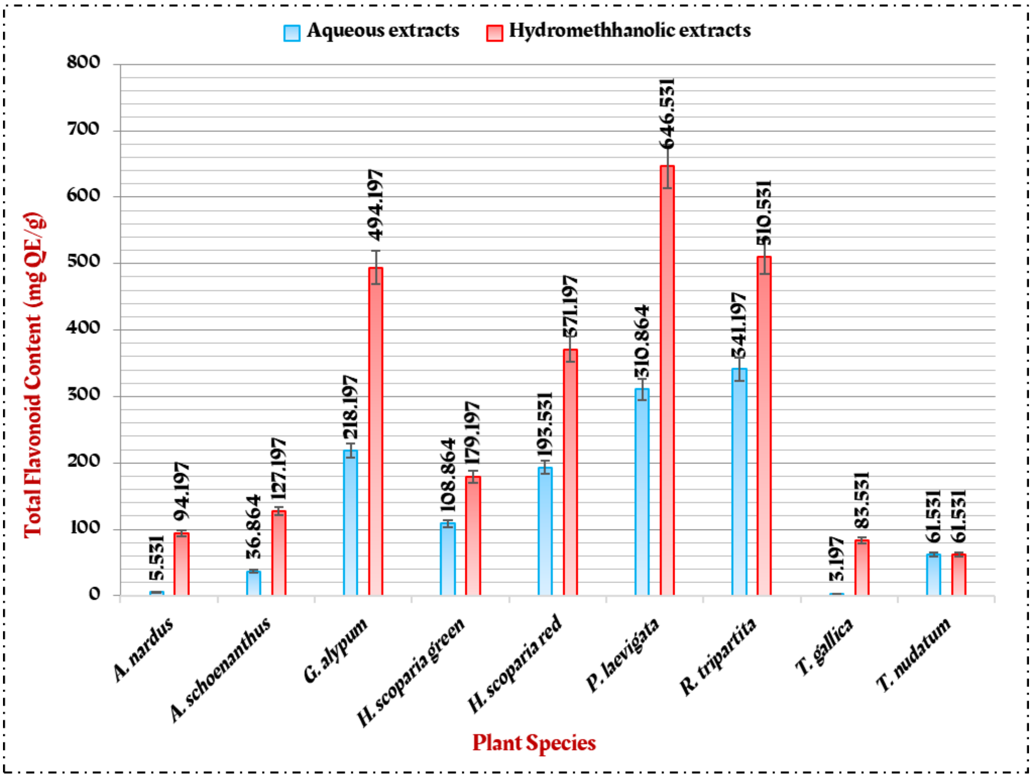


Figure III.27. Total Flavonoids Contents of Plant Extracts

Flavonoids comprise a particular group of phenolic compounds with a structure based on the diphenyl propane carbon skeleton. However, flavonoids contain multiple hydroxyl groups and show increased antioxidant activities. Flavonoids and phenolic compounds are beneficial for human health, as indicated by epidemiological and *in vitro* evidence of their antioxidant, cardioprotective, and anticarcinogenic activities; they are also known to protect against other non-transmissible chronic diseases (Khettaf et al., 2016; Kumar and Goel, 2019).

III.6. Total Polysaccharide Contents (TPSC)

Polysaccharide is a high molecular weight polymer, consisting of at least ten monosaccharides mutually joined by glycosidic linkages. The glycosyl moiety of hemiacetal or hemiketal, together with the hydroxyl group of another sugar unit, formed the glycosidic linkages. Unlike protein and nucleic acid, the structure of polysaccharide is far more complicated based on the differences in the composition of monosaccharide residues, glycosidic linkages, sequence of sugar units, degrees of polymerization, and branching point (Cui, 2005; J. Wang et al., 2016)

There is no one direct measurement of polysaccharides since there are mixed complex and combination of variety of monosaccharides (P. Wang et al., 2016). Phenol sulfuric acid method is a colorimetric method widely used to determine the total carbohydrate content of bacterial and plant polysaccharides (Rühmann et al., 2015)**.**

Monosaccharides, oligosaccharides, and polysaccharides rearrange themselves to furfural derivatives by the action of sulfuric acid at elevated temperature and furfural derivatives then react with phenol to give colored compounds. The absorbance of the characteristic color was measured at 490 nm. The calibration curve for different concentrations of glucose is represented in Figure III.28.

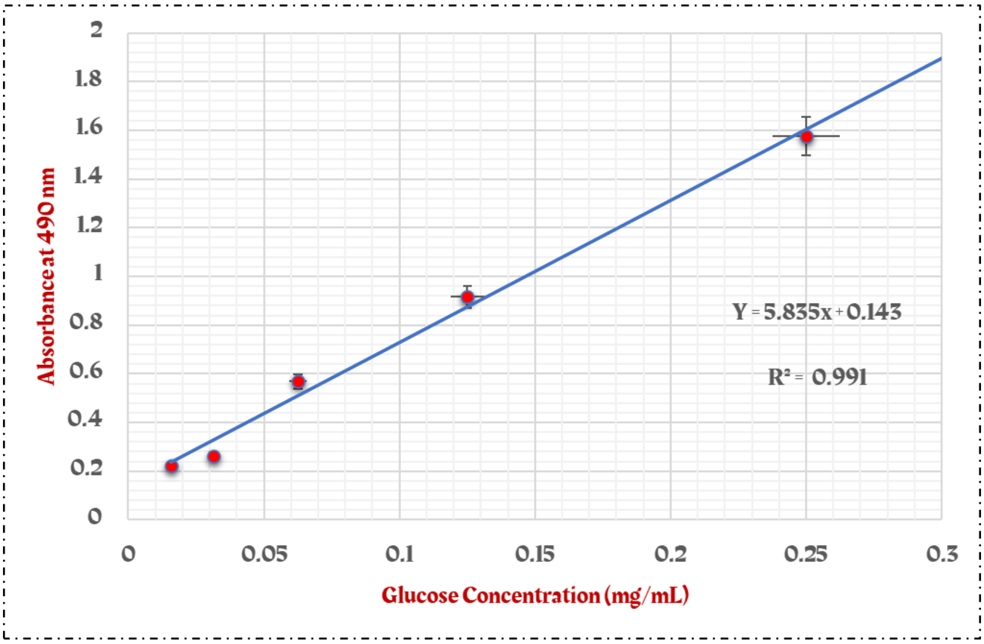


Figure III.28. Glucose Calibration Curve

Using the proposed method, the calibration curve was found to be linear. A correlation coefficient of 0.991 indicates good linearity between the concentration and absorbance. The total polysaccharide content of the plant species extracts was calculated using a regression equation obtained from the calibration curve.

Total polysaccharide contents in hydromethanolic extract were placed between 96.405±0.003 and 356.609±0.005 mg GE/g while it ranges between 116.282±0.002 and 336.989±0.043 mg GE/g in water extracts of plant samples (Figure III.29).

Among all the extracts, hydromethanolic extracts of *A. schoenanthus*, *R. tripartita*, and *H. scoparia* green have the highest polysaccharide content (356.609±0.005, 350.440±0.049, and 344.957±0.046 mg GE/g respectively), followed by the aqueous extracts of *T. gallica* and *H. scoparia* green (336.989±0.043 and 315.055±0.017 mg GE/g). Furthermore, the hydromethanolic extract of *H. scoparia* red and the aqueous extract of *P. laevigata* obtained the lowest polysaccharide content (96.405±0.003 and 116.282±0.002 mg GE/g respectively) among all the tested extracts.

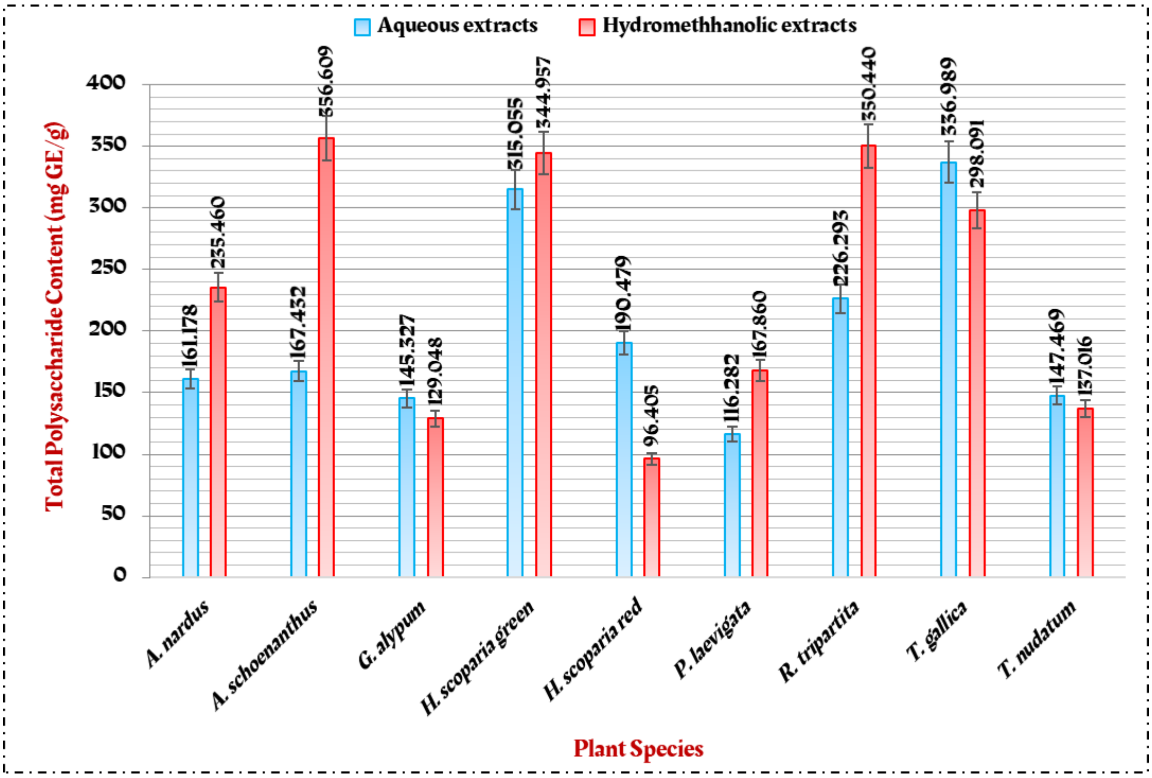


Figure III.29. Total Polysaccharide Contents of Plant Extracts

Due to the arduous isolation and purification procedures, research on polysaccharides is comparatively less compared to other secondary metabolites (Bose, 2016). In recent years, polysaccharides from plants, animals, and microorganisms have piqued the interest of many researchers, owing to their many biological activities. Plant-based polysaccharides act as antioxidants, antitumor agents, antivirals, anticoagulants, and immune-stimulating agents (Cho et al., 2020; W. Raja et al., 2016; Y. T. Wang et al., 2016; Zhong et al., 2019).

Furthermore, there is increasing evidence that many kinds of polysaccharides possess strong antioxidant activities (Olasehinde et al., 2017), and these compounds are usually nontoxic and cause few adverse effects. Therefore, polysaccharides may potentially be developed as natural antioxidant products (Namasivayam et al., 2014; J. Wang et al., 2016; P. Wang et al., 2016).

III.7. High-Performance Liquid Chromatography Analysis

One of the chromatographic techniques which have been widely applied to separate and purify a mixture of compounds in various analytical research areas is high performance liquid chromatography (HPLC). It can be used to carry out the separation of complex mixtures of compounds and provide qualitative and quantitative information on the samples that are useful for the identification and determination of sample components (Dahimiwal et al., 2013).

A polyphenol investigation using HPLC was carried out in two hydromethanolic extracts: *P. laevigata* and *R. tripartita*. Peak identification was confirmed by comparison of retention time and spectral data with adequate parameters of standards used in this study (Quercetin, Catechin, Caffeic acid, Ferulic Acid, Naringenin, and p-Coumaric acid).

Figure III.30 represents the hydromethanolic extracts HPLC chromatograms of *P. laevigata* and *R. tripartita* respectively. While Figure III.31 represents the HPLC chromatograms of the standard phenolic compounds: Quercetin, catechin, Caffeic acid, Ferulic Acid, Naringenin, and p-coumaric acid with retention times 2,943; 26,127; 31,637; 38,537; 42,877 and 42,427 min respectively.

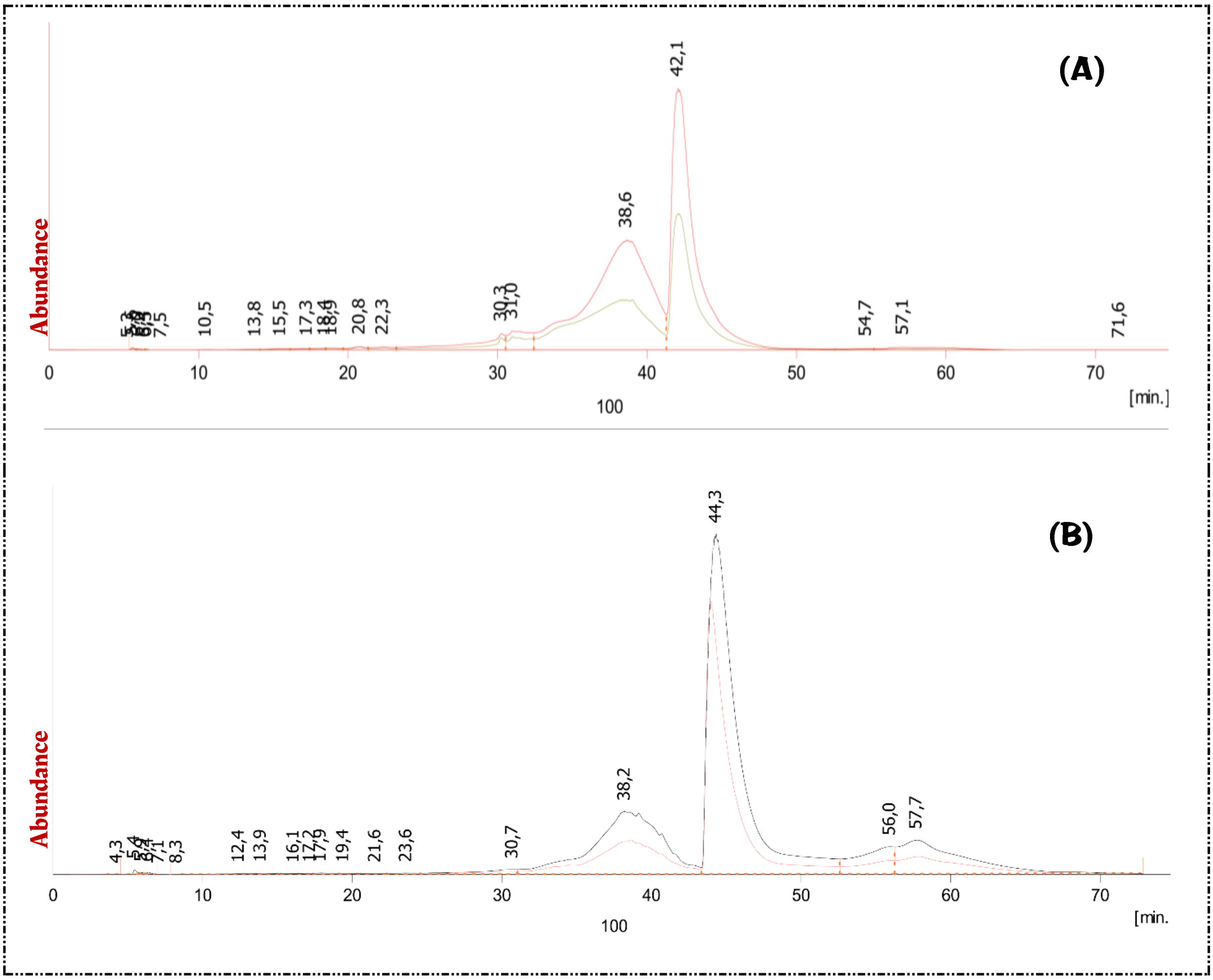


Figure III.30. HPLC Profile of Hydromethanolic Extracts:
(A) *P. laevigata* and (B) *R. tripartita*

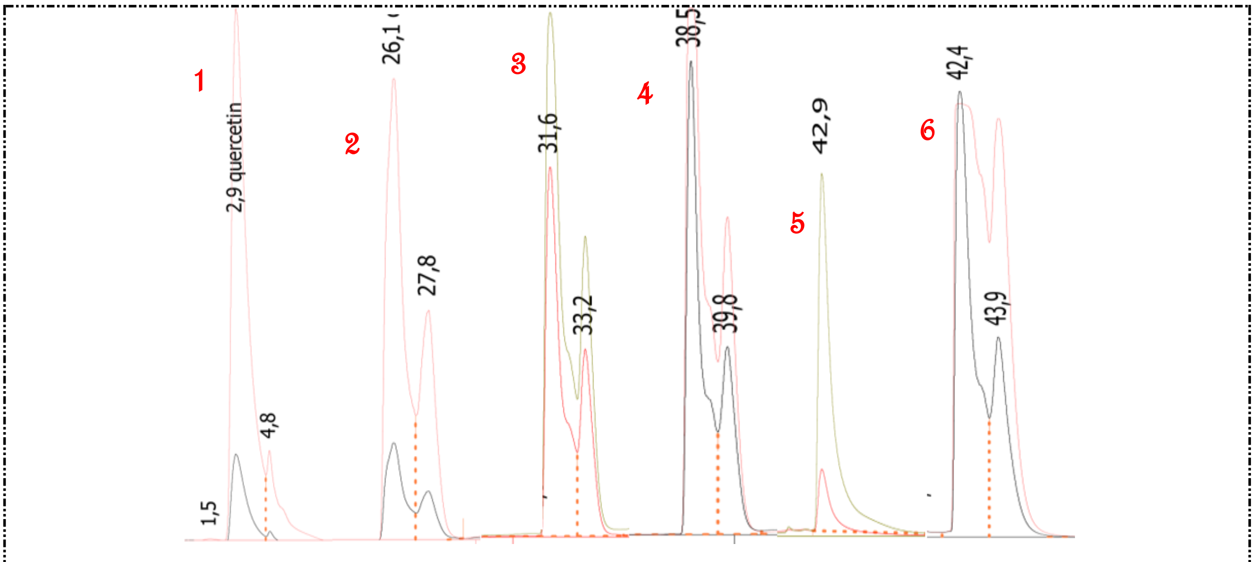


Figure III.31. HPLC Chromatogram of Standard Phenolic Compounds:
(1) Quercetin, (2) Catechin, (3) Caffeic acid, (4) Ferulic Acid, (5) p-Coumaric acid and (6) Naringenin

Table III.10. HPLC Data of Standard Phenolic Compounds

	Reten. Time [min]	Area [mV.s]	Height [mV]	Area [%]	Height [%]	Compound Name
1	2,943	89571,218	1478,967	85,9	85,0	**Quercetin**
2	26,127	32436,586	561,663	68,3	66,8	**Catechin**
3	31,637	168093,309	3258,878	58,3	60,1	**Caffeic acid**
4	38,537	149259,747	3361,893	66,1	61,3	**Ferulic acid**
5	42,427	154087,860	3281,863	62,9	65,5	**p-coumaric acid**
6	43,877	115591,531	2101,039	100,0	100,0	**Naringenin**

It can be observed that there are significant peaks indicating the presence of many compounds. The major identified compounds in the hydromethanolic extract of *P. laevigata* were: Naringenin and Ferulic acid (0.465 and 0.401 mg/mL respectively) and, followed by p-coumaric acid and caffeic acid in smaller amount (0.043 and 0.018 mg/mL respectively). Whereas, the major identified compounds in the hydromethanolic extract of *R. tripartita* were: Naringenin and p-coumaric acid (0.762 and 0.572mg/mL respectively), followed by Ferulic acid (0.253 mg/mL).

In the previous studies with *Rhus* extracts, 2,4-dihydroxybenzoic acid, protocatechuic acid, caffeic acid, chlorogenic acid, p-coumaric acid, phloretin-20-O-glucoside, kaempferol-3-Oglucoside, quercetin, butein, and kaempferol, gallic acid, 2,6,3’,4’-tetrahydroxy-2-benzylcoumaran-3-one, fustin, fisetin, and sulfuretin have been reported as major phenolic compounds (Jin et al., 2015; Kim et al., 2013). This composition and contents of the ingredients varied as the *Rhus* specie was different.

The contribution of these minor phenolic compounds to biological functions could not be thus neglected. Diverse pharmacological activities have been accredited to phenolic acids for instance, caffeic acid has with antioxidant, anti-inflammatory, antibacterial, antifungal; ferulic acid with anti-inflammatory, antifungal; cinnamic acid with antifungal, anthelmintic, natural protection against infections by pathogenic microorganisms. Naringenin are considered as one of the main groups of compounds responsible for the sedative activity (Iloki-Assanga et al., 2015; Karim et al., 2020; Lourenço et al., 2019).

IV. *In Vitro* Antioxidant Activity

Medicinal plants may contain a wide variety of free radical scavenging molecules, such as phenolic compounds (e.g. phenolic acids, flavonoids, quinones, coumarins, tannins), nitrogen compounds (alkaloids, amines), vitamins, terpenoids, and some other endogenous metabolites, which are rich in antioxidant activity (Salehi et al., 2020; Shi et al., 2016)**.** Epidemiological studies have shown that many of these antioxidant compounds possess anti-inflammatory, antiatherosclerotic, antitumor, antimutagenic, anticarcinogenic, antibacterial, or antiviral activities to a greater or lesser extent (Dehkordi et al., 2015; Kumar et al., 2017; Le Anh Dao et al., 2020; Szerlauth et al., 2019).

In vitro antioxidant analysis of natural compounds depends upon their free radical scavenging potential. *In vitro* analysis often uses chemicals and reagents to generate free radicals so that the radical scavenging ability of the test antioxidant can be determined. A great number of *in vitro* methods have been developed to measure the efficiency of natural antioxidants either as pure compounds or as plant extracts such as: DPPH Radical Scavenging Assay (DPPH), Ferric reducing antioxidant power (FRAP) and Total Antioxidant Capacity (TAC). These methods are popular due to their high speed and sensitivity. However, it is essential to use more than one method to evaluate antioxidant capacity of plant materials because of the complex nature of phytochemicals (Essien et al., 2017)**.**

Ascorbic acid (Vitamin C) is commonly recognized as a major natural antioxidant and nutrient in our diet and is found to possess anti-carcinogenic activity(Liu et al., 2020). Of late, more attention has been focused on the determination of the total antioxidant capacity of compounds using the Ascorbic acid equivalent antioxidant capacity assays where the value is assigned by comparing the antioxidant capacity or radical scavenging ability of an antioxidant to that of Ascorbic acid (Annegowda et al., 2010; Liu et al., 2020)**.**

In this work, the *in vitro* antioxidant activity of crude aqueous and hydromethanolic extracts of *A. nardus*, *A. schoenanthus*, *G. alypum*, two species of *H. scoparia*, *P. laevigata*, *R. tripartita*, *T. gallica* and *T. nudatum*, compared to that ascorbic acid as positive reference standard, were evaluated using three different assays, namely Total Antioxidant Capacity (TAC), Ferric Reducing Antioxidant Power (FRAP) and DPPH Radical Scavenging Assay (DPPH).

IV.1. Total Antioxidant Capacity (TAC)

Total antioxidant capacity is a better way of depiction of combined effect of phenolics, flavonoids and other reducing compounds in the plant extracts and is expressed in terms of ascorbic acid equivalents (AAE). The phosphomolybdenum method is based on the reduction of Mo (VI) to Mo (V) by the action of antioxidant compounds and the formation of a green phosphate - Mo (V) complex with a maximal absorption at 695 nm.

The TAC assay indicated a wide variation of total antioxidant capacity in the different extracts, ranging from 49.238±0.009 to 361.507±0.326 mg AAE/g in the hydromethanolic extracts while it ranges of 3.497±0.004 to 426.581±0.1812 mg AAE/g in the aqueous extracts of plant samples (Figure III.32). The extracts of *G. alypum*, *H. scoparia* red, *P. laevigata*, *R. tripartita* and *T. gallica* showed a high total antioxidant capacity value in comparing with the other plant species extracts.

Among all the extracts, the aqueous and hydromethanolic extract of *R. tripartita* (426.581±0.1812 and 361.507±0.326 mg AAE/g respectively) and the hydromethanolic extracts of *T. gallica*, *H. scoparia* red and *P. laevigata* (295.166±0.165, 289.673±0.051 and 264.108±0.170 mg AAE/g respectively) had the highest total antioxidant capacity, followed by the aqueous extract of *H. scoparia* red and the hydromethanolic extract of *G. alypum* (262.101±0.149 and 218.895±0.109 mg AAE/g respectively).

Furthermore, the aqueous extracts of *A. nardus* and *T. nudatum* obtained the lowest antioxidant capacity (3.497±0.004 and 17.230±0.025 respectively), followed by the hydromethanolic and aqueous extracts of *A. schoenanthus* (49.238±0.009 and 51.774±0.072 mg AAE/g respectively).

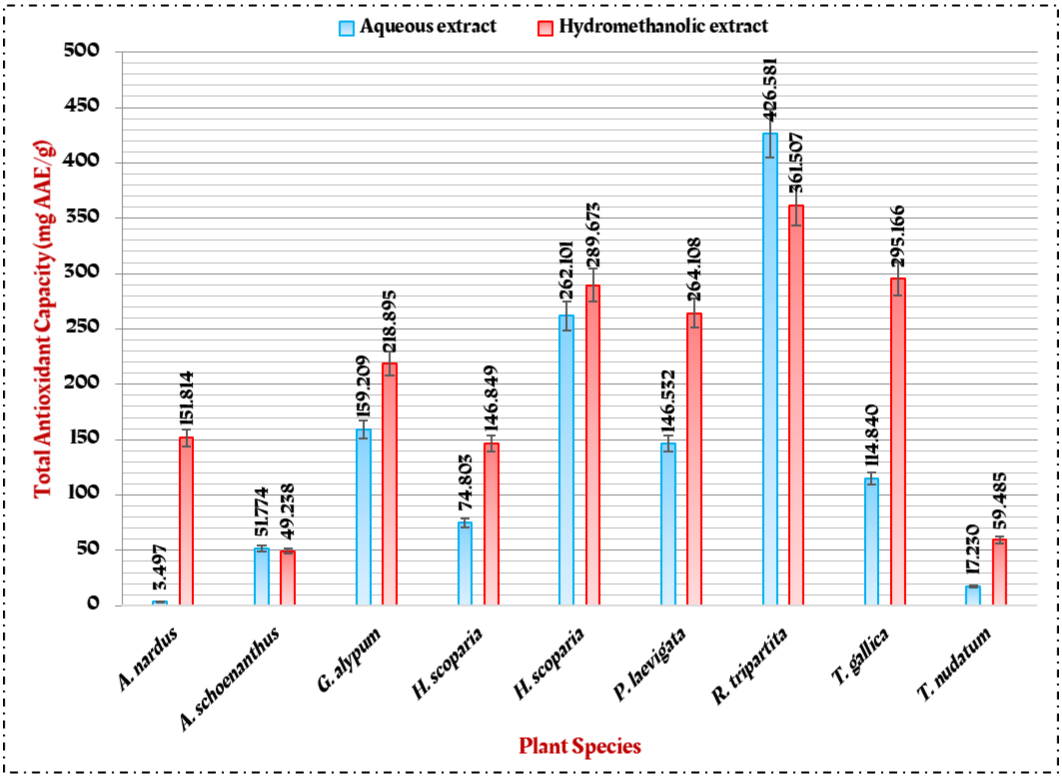


Figure III.32. Total Antioxidant Capacity of Plant Extracts

Screening bioactive compounds from natural materials based on antioxidant potentials is widely adopted at present. Recently, natural materials are proved to be a highly promising source of antioxidants, since a wide range of bioactive constituents derived from them, such as flavonoids, polyphenols, polysaccharides, and others, have been reported to possess strong antioxidant abilities (Guo et al., 2015)

IV.2. Ferric Reducing Antioxidant Power (FRAP)

The FRAP assay may be assigned as an important index for the antioxidation effect of antioxidants. In general, iron exists in two distinct oxidation states that is, active ferrous ion (Fe^{2+}) and inactive ferric ion (Fe^{3+}) (Gülçin et al., 2007)**.** For the measurements of the ferric reducing antioxidant power, the Fe^{3+}- Fe^{2+} transformation was investigated in the presence of the different extracts by Prussian blue method. In this assay, the presence of reductant in the antioxidant sample causes the reduction of the Fe^{3+} (ferricyanide complex) to the Fe^{2+} (ferrous form), so the reducing power of the sample can be monitored by measuring the formation of Prussian blue at 700 nm (Mahbubur et al., 2015)**.**

The FRAP values were expressed as milligrams Ascorbic acid equivalent ferric reducing antioxidant potency per gram of plant extract (mg AAEFRAP/g).

As shown in Figure III.33, the hydromethanolic extracts of all the plant samples showed a very high ferric reducing antioxidant potency in comparing with the aqueous extracts. The reductive potential of the different plant exhibited a dose-dependent activity within a concentration range of 84.322±0.016 to 624.194±0.294 mg AAEFRAP/g in the hydromethanolic extracts while it ranges of 0.549±0.002 to 176.473±0.063 0.079 mg AAEFRAP/g in the aqueous extracts of plant samples.

Among all the extracts, the hydromethanolic extracts of *R. tripartita*, *P. laevigata*, *T. gallica* and *H. scoparia* red had the highest reductive ability (624.194±0.294, 589.195±0.054, 470.423±0.141 and 436.914±0.153 mg AAEFRAP/g respectively), followed by the hydromethanolic extract of *G. alypum*, *H. scoparia* green and the aqueous extract of *R. tripartita* (286.495±0.031, 212.774±0.020 and 176.473±0.063 mg AAEFRAP/g respectively). Furthermore, the aqueous extracts of *T. gallica*, *A. nardus*, *T. nudatum* and *A. schoenanthus* showed the lowest reductive ability (0.549±0.002, 1.852±0.006, 2.225±0.001 and 4.272±0.003 AAEFRAP/g respectively).

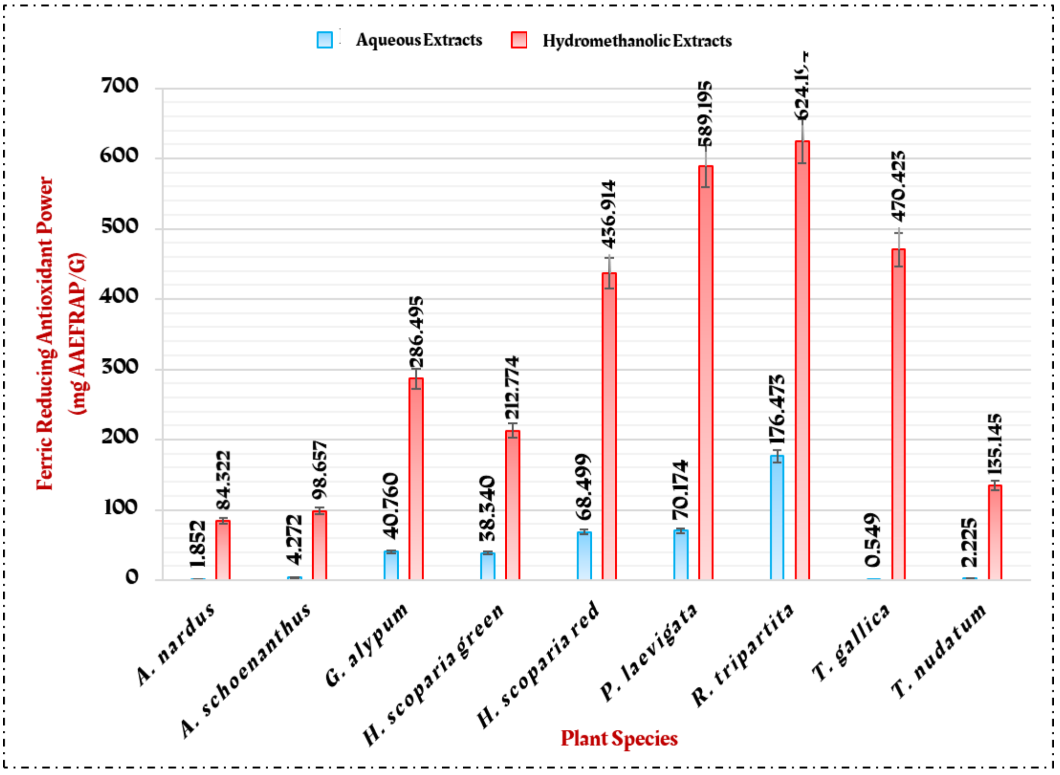


Figure III.33. Ferric Reducing Antioxidant Power of Plant Extracts

The reductive ability, a significant indicator for its potential antioxidant activity might be because of a hydrogen-donating ability and is generally associated with the presence of reductones (Xiao et al., 2011). For the measurement of reducing power, the potassium ferricyanide reduction method was employed to detect the reductive activities of the different extracts (Funde, 2015).

IV.3. DPPH Radical Scavenging (DPPH)

DPPH (1,1-diphenyl-2-picrylhydrazyl) analysis is one of the best-known, accurate, and frequently employed methods for evaluating antioxidant activity (R. Raja et al., 2016). It is a stable free radical because of its spare electron delocalization over the whole molecule. The donation of H^+ to the DPPH radicals made a corresponding change from violet color to pale yellow in the solution. The concentration of DPPH at the end of a reaction will depend on the concentration and structure of the compound being scavenged (Naik et al., 2003). The DPPH scavenging also made a proportionate decrease in its absorbance at 517nm. The major advantage of this method over other assays is its broad solvent compatibility with aqueous and polar and nonpolar organic solvents (Charles, 2013).

Qualitatively, the 2,2,diphenyl-1-picrylhydrazyl (DPPH) assay on TLC and Microtiter plates was used as a screening test for the radical scavenging ability of the compounds presented in the different extracts.

The DPPH method measures electron-donating activity of other compounds in the mixture and hence provides an evaluation of antioxidant activity due to free radical scavenging. Any molecule that can donate an electron or hydrogen to a mixture will react with and bleach DPPH. DPPH is reduced from a purple compound to a light-yellow compound by electrons from oxidant compounds. Reaction of DPPH with hydroxyl groups involves a homolytic substitution of one of the phenyl rings of DPPH yielding 2-(4-hydroxyphenyl)-2-phenyl-1- picryl hydrazine as a major product whilst 2-(4nitrophenyl)-2phenyl-1-picrylhydrazine is also formed via a series of secondary processes (Masoko and Eloff, 2007; Naik et al., 2003; Ogbonnaya and Chinedum, 2013).

Table III.11. TLC Qualitative DPPH Assay

		A. nardus	*A. schoenanthus*	*G. alypum*	*H. scoparia* green	*H. scoparia* red	*P. laevigata*	*R. tripartita*	*T. gallica*	*T. nudatum*
TLC essay	**A. Extracts**	+	+	+++	++	+++	++	+++	+	+
	HM. Extracts	++	++	+++	++	+++	+++	+++	+++	+
Multiplate assay	**A. Extracts**	+	+	+++	++	+++	++	+++	+	+
	HM. Extracts	++	++	+++	++	+++	+++	+++	+++	+

NB: The degree of activity, determined qualitatively from observation of the yellow color intensity: Weak (+), Moderate (++), and Strong (+++)

In this study, The TLC-DPPH and Microtiter plate screening methods indicated the presence of antioxidant compounds in all the extracts tested. The degree of activity of all the samples tested was determined qualitatively from observation of the yellow color intensity (Figure III.34).

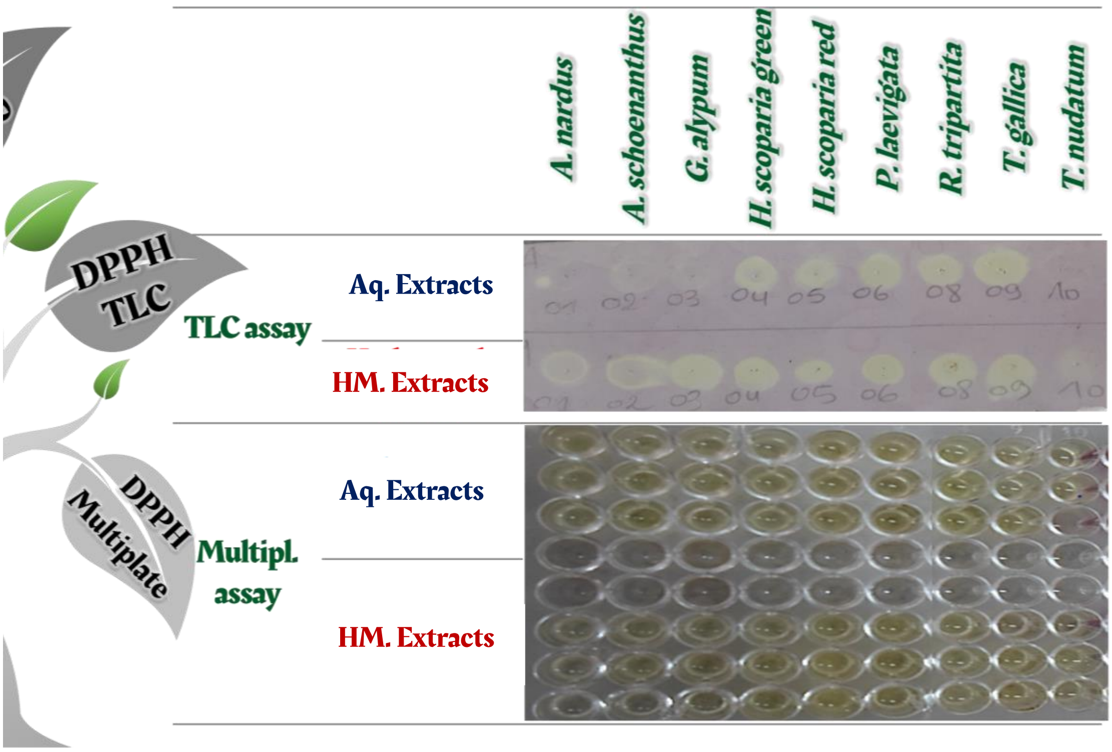


Figure III.34. DPPH TLC and Microtiter Plate Assays

The species *G. alypum, H. scoparia* red, and *R. tripartita* showed the most prominent antioxidant activity. The hydromethanolic extracts of *T. gallica* and *P. laevigata* are also a good candidate to isolate antioxidant compounds. This analysis revealed significant scavenging of free radicals by all extracts, in a dose-dependent manner and this may be attributed to their electron donating ability.

Qualitative DPPH assay was successfully used in this study to systematically assess the total antioxidant activity of the selected species extracts. This effective and efficient method can be used for systematic screening of medicinal herbs for their relative antioxidant content. It is simple, fast, reliable, inexpensive, and also very adaptable to identify antioxidant compounds in medicinal plants.

Quantitatively, the amount of sample required to decrease the initial DPPH concentration (IC_{50}) by 50% is a parameter widely used to measure the antioxidant activity. The lower the IC_{50} value, the higher the antioxidant activity (Gallego et al., 2017).

The results expressed as Inhibition Concentration IC_{50} (mg/mL) for the different extracts of the tested plants species and three standards (acid Ascorbic, acid gallic and quercetin) are summarized in Figure III.35.

Among all the extracts, hydromethanolic and aqueous extracts of *R. tripartita* exhibited higher total antioxidant activity with a very low IC_{50} (15.838 and 19.539 mg/mL respectively) followed by the hydromethanolic extract of *T. gallica* (19.203 mg/mL), hydromethanolic and aqueous extracts of *H. scoparia* red (29.123 and 32.176 mg/mL respectively), hydromethanolic extract of *P. laevigata* (33.367 mg/mL), hydromethanolic and aqueous extracts of *G. alypum* (38.287 and 53.273 mg/mL respectively).

Furthermore, the aqueous extracts of *T. gallica* and *T. nudatum* obtained the lowest activity (461.368 and 354.937 mg/mL) between all the extracts, followed by the aqueous extracts of *A. nardus, A. schoenanthus* (251.466 and 178.083 mg/mL respectively), and the hydromethanolic extracts of *T. nudatum* (150.044 mg/mL).

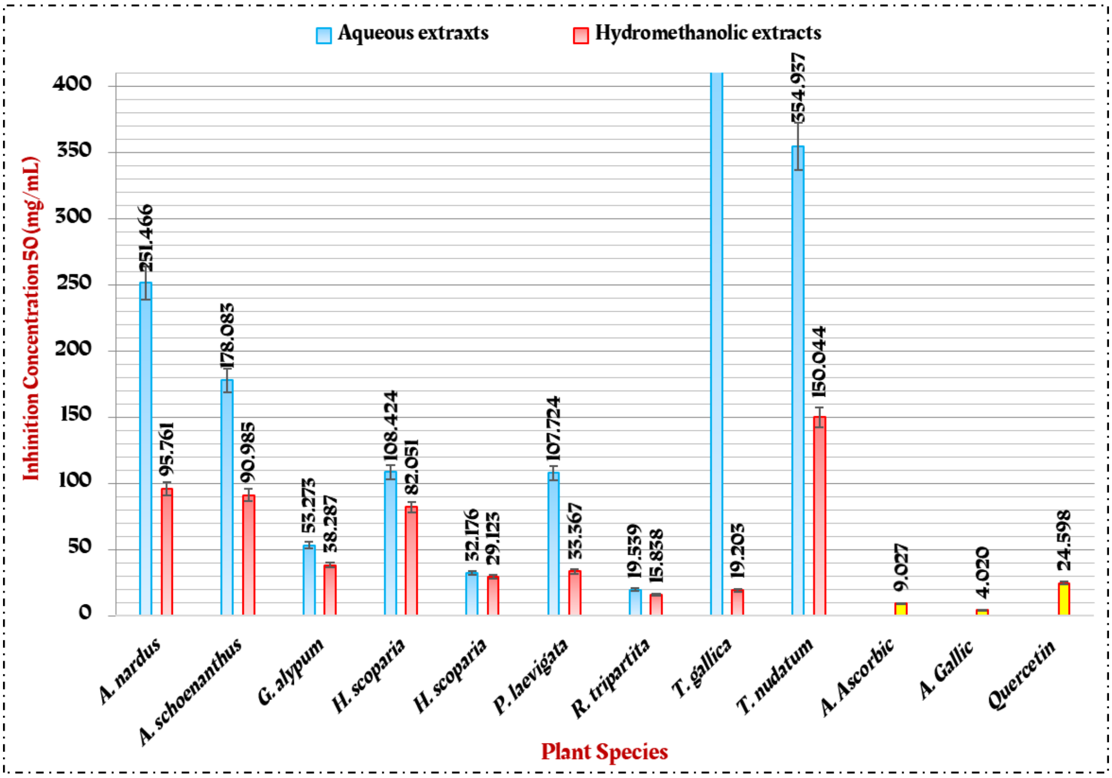


Figure III.35. DPPH Radical Scavenging Activity of Plant Extracts

Acid ascorbic, acid gallic and quercetin used in this study, are standard antioxidants and can be used as a good indicator for comparing scavenging activity between the extracts. None of the analyzed species showed higher results than acid gallic and acid ascorbic (4.020 and 9.027 mg/mL respectively). However, the standard used were pure and may actually have higher antioxidant activity compared to the crude extracts). The activity of *R. tripartita* extracts and the hydromethanolic extract of *T. gallica* were high not only on comparing with other plants, but also it was elevated *vis-à-vis* the antioxidant standard “quercetin” (150.044 mg/mL).

The detection of antioxidant activity of the studied plant species enhances their importance as a potential new source of natural drugs and nutritional supplements, which should be investigated more in future with greater attention.

V. *In Vitro* Antibacterial Activity

The usage of medicinal plants for primary health care needs by millions of people in developing world is still occupying a prominent position. The folk remedies are considered readily available, cheap and time tested (Gupta et al., 2016).

The medicinal plants are important source of potentially bioactive constituents for the development of new chemotherapeutic agents. The first step towards this goal is the *in vitro* antimicrobial activity (Darshan Singh et al., 2016)**.** Nine plants species, namely, *A. nardus, A. schoenanthus, G. alypum*, two species of *H. scoparia* green & red, *P. laevigata, R. tripartita, T. gallica* and *T. nudatum*, were collected from different regions of Bechar province.

The aqueous and the hydromethanolic extracts of the selected plant species were investigated to evaluate their antibacterial activity against ten bacterial trains including seven reference strain, *Bacillus cereus* (ATCC 11778), *Enterococcus faecalis* (ATCC 29212), *Staphylococcus aureus* (ATCC 25922), *Escherichia coli* (ATTC 25923), *Klebsiella pneumoniae, Pseudomonas aeruginosa* (ATCC 27853), *Salmonella typhi* (ATCC 25922), and three clinically isolated strains, *Escherichia coli* (UTI), *Escherichia coli* (VI) and *Staphylococcus aureus* (*SI*), using disc diffusion method.

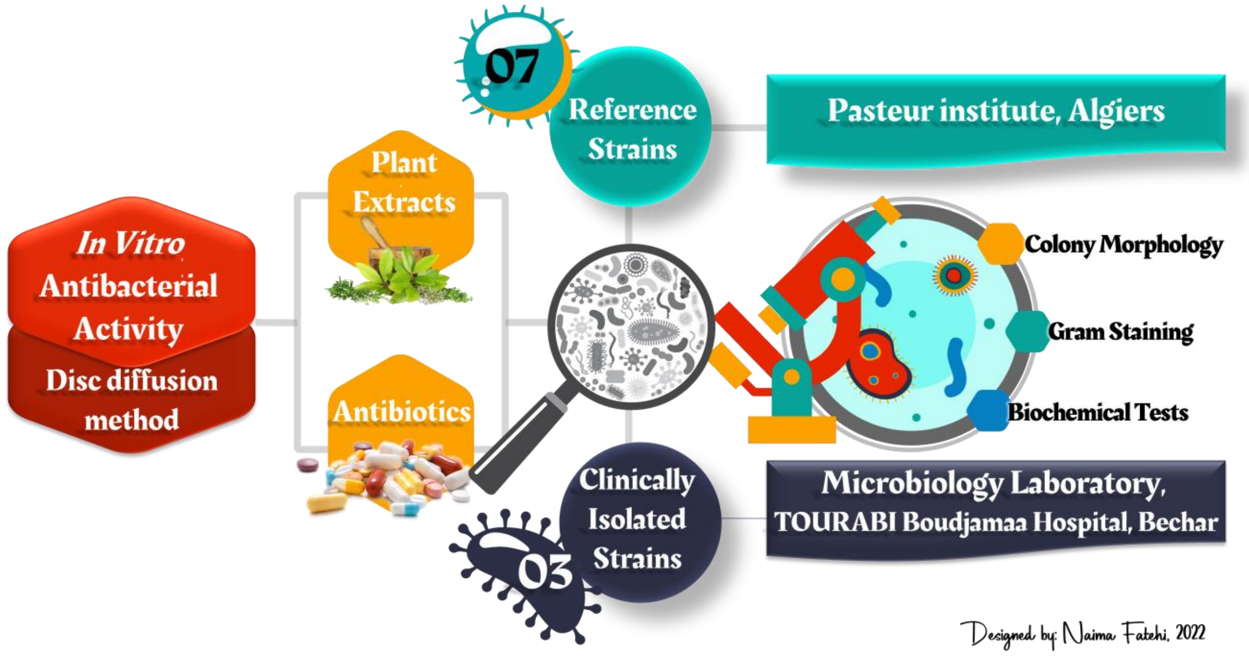


Figure III.36. *In Vitro* Antibacterial Activity Procedure

V.1. Identification and Characterization of Clinical Isolates

The *Escherichia coli* and *Staphylococcus aureus* species isolated from clinical samples were obtained from the Microbiology Laboratory, Tourabi Boudjamaa Hospital, Bechar. Conventional bacteriological methods such as colony morphology, gram staining (Table III.12) and biochemical tests (Table III.13) were used for identification of the clinical isolates (Forbes et al., 2007; Frerichs and Millar, 1993)**.**

Table III.12. Colony Morphology and Gram Staining

Bacterial strain	Gram	Microscopic observation
Escherichia coli (vaginal Infection)	-	Bacilli
Escherichia coli (urinary tract infection)	-	Bacilli
Staphylococcus aureus (skin infections)	+	Cocci in grape-like clusters

Table III.13. Biochemical Test Reactions for *E. Coli* and *S. Aureus* Species

Escherichia coli

Lactose fermentation	Catalase	Simmon' s Citrate	Indole Production	Nitrate Reduction	Methyl Red	Voges-Proskauer	Urease	Glucose	Mannitol	Lactose	Salicin	Sucrose
+	+	-	+	+	+	-	-	+	+	+	+	+

Staphylococcus aureus

Oxidase	Catalase	Indole Production	Nitrate Reduction	Methyl Red	Voges-Proskauer	Glucose	Mannitol	Maltose	Lactose	Raffinose	Sucrose	Haemolysis	Coagulase
	+	-	+	+	+	+	+	+	+	-	+	+	+

V.2. Antibacterial Activity of Plant Extracts

In-vitro antibacterial screening was generally performed by paper disc diffusion method for the primary selection of the compound as therapeutic agent.

Table III.14 summarizes the bacterial growth inhibition of both aqueous and hydromethanolic extracts of the screened plant species. The results revealed that the most plant extracts were potentially effective in suppressing microbial growth of the tested bacteria with variable potency. The different extracts of *H. scoparia* red, *P. laevigata*, *R. tripartita*, and *T. gallica* showed significant antibacterial activity against the most investigated bacteria as assessed by the inhibition zone diameter of each extract (Figure III.37).

The extracts of *T. gallica* were found more effective against most tested bacteria, showing a significant inhibition zone ranging between 13.3 and 15.6 mm, recorded against the reference gram-negative bacteria (*Escherichia coli*, *Klebsiella pneumoniae* and *Pseudomonas aeruginosa*). The extracts of *R. tripartita* were also found effective against the reference gram-negative bacteria *(Escherichia coli* and *Pseudomonas aeruginosa*) showing a significant inhibition zone ranging between 13.3 and 14.6 mm. The most significant inhibition zone recorded against the reference gram-positive was detected by the hydromethanolic extracts of *P. laevigata* and *H. scoparia* green against *Staphylococcus aureus* (13.0±1.7 and 13.3±2.0 mm respectively).

On the other hand, the species of *H. Scoparium* exhibited inhibitory effect against all the tested pathogenic strains (100%), *A. schoenanthus*, *P. laevigata*, and *T. gallica* were effective against nine of them (90%). Whereas *A. nardus*, *R. tripartita* and *T. nudatum* were effective against seven photogenic species only (70%).

Table III.14. Antibacterial Activity of Plants extracts

				A. nardus	*A. schoenanthus*	*G. alypum*	*H. scoparia green*	*H. scoparia red*	*P. laevigata*	*R. tripartita*	*T. gallica*	*T. nudatum*
Standards	Gram (+) bacteria	***Bacillus cereus***	**Aq. Ext**	**9.6±0.5**	**9.6±0.5**	**11.3±0.5**	**10.0±1.0**	**9.0±1.7**	6.0±0.0	6.0±0.0	**9.6±0.5**	**8.0±2.0**
			Mth. Ext	8.0±0.0	**9.3±1.1**	8.6±0.5	8.0±1.7	7.3±0.5	6.0±0.0	6.0±0.0	8.0±0.0	6.0±0.0
		Enterococcus feacalis	**Aq. Ext**	7.0±1.0	7.3±2.3	8.3±0.5	6.6±0.5	8.6±1.5	7.3±1.1	8.0±0.0	7.3±1.1	6.6±0.5
			Mth. Ext	6.0±0.0	6.6±0.5	6.3±0.5	8.0±0.0	6.6±1.1	6.3±0.5	**10.3±1.5**	7.6±1.1	6.0±0.0
		Staphylococcus aureus	**Aq. Ext**	7.3±0.5	8.6±0.5	8.6±0.5	**9.0±1.0**	**10.3±1.5**	7.6±0.5	7.6±1.5	**10.3±0.5**	**9.6±0.5**
			Mth.Ext	7.6±0.5	**9.3±1.5**	**9.6±0.5**	**13.0±1.7**	7.0±1.7	**13.3±2.0**	8.0±0.0	**9.6±1.5**	7.3±0.5
	Gram (-) bacteria	***Escherichia coli***	**Aq. Ext**	**9.3±0.5**	**10.3±0.5**	6.0±0.0	7.6±0.5	**11.3±1.1**	**9.6±0.5**	**13.3±2.0**	**15.0±1.4**	7.6±0.5
			Mth.Ext	6.3±0.5	7.6±1.5	6.3±0.5	8.3±0.5	**12.0±2.0**	**10.6±1.5**	**14.3±0.5**	**13.3±1.1**	7.6±1.5
		Klebsiella pneumoniae	**Aq. Ext**	**9.3±0.5**	8.0±0.0	**10.0±1.0**	9.3±0.5	7.6±1.5	6.6±2.9	7.3±1.5	**13.3±2.5**	**9.3±1.1**
			Mth.Ext	8.0±2.0	**9.6±1.5**	9.0±1.0	**9.3±2.0**	9.6±2.3	6.0±0.0	**8.0±1.7**	**14.0±1.0**	6.6±0.5
		Pseudomonas aeruginosa	**Aq. Ext**	6.0±0.0	**9.6±1.1**	6.6±1.1	8.3±0.5	9.0±2.0	**12.0±0.0**	**14.3±2.0**	**15.6±0.5**	6.0±0.0
			Mth.Ext	6.0±0.0	7.6±2.8	**12.6±2.5**	7.0±0.0	**11.6±2.0**	**13.6±1.1**	**14.6±1.2**	**11.6±0.5**	6.0±0.0
		Salmonella typhi	**Aq. Ext**	6.0±0.0	7.0±0.0	8.3±1.5	8.0±1.0	6.0±0.0	**10.0±1.0**	6.0±0.0	6.0±0.0	7.3±0.5
			Mth.Ext	6.0±0.0	7.0±1.0	8.0±0.0	6.0±0.0	7.0±0.0	7.3±0.5	6.0±0.0	**10.0±1.0**	7.3±0.5
Clinical isolates		***Escherichia coli*** (Urinary tract infection)	**Aq. Ext**	6.0±0.5	6.0±0.0	6.6±0.5	6.3±0.5	7.3±0.5	8.6±0.5	6.0±0.0	6.0±0.0	6.3±0.5
			Mth. Ext	6.6±0.5	6.0±0.0	7.6±0.5	6.6±0.5	6.0±0.0	8.0±1.0	6.0±0.0	6.0±0.0	8.3±0.5
		Escherichia coli (Vaginal Infection)	**Aq. Ext**	6.0±0.0	6.3±0.5	6.0±0.0	**10.3±0.5**	6.0±0.0	7.3±0.5	**8.0±1.0**	**8.3±1.5**	6.0±0.0
			Mth. Ext	6.0±0.0	7.6±0.5	6.0±0.0	**11.3±0.5**	9.3±0.5	8.0±0.0	6.0±0.0	**9.6±0.5**	6.0±0.0
		Staphylococcus aureus (Skin infections)	**Aq. Ext**	8.3±0.5	6.6±0.5	6.0±0.0	8.6±0.5	**11.3±0.5**	**10.3±0.5**	**9.6±0.5**	**9.6±0.5**	7.3±0.5
			Mth.Ext	**9.0±0.0**	**10.3±0.5**	6.0±0.0	**11.0±1.0**	**11.3±0.5**	**10.6±1.1**	**10.3±0.5**	**10.0±1.0**	**10.0±0.0**

Aq. Ext: Aqueous extract **Mth. Ext**: Hydromethanolic extract

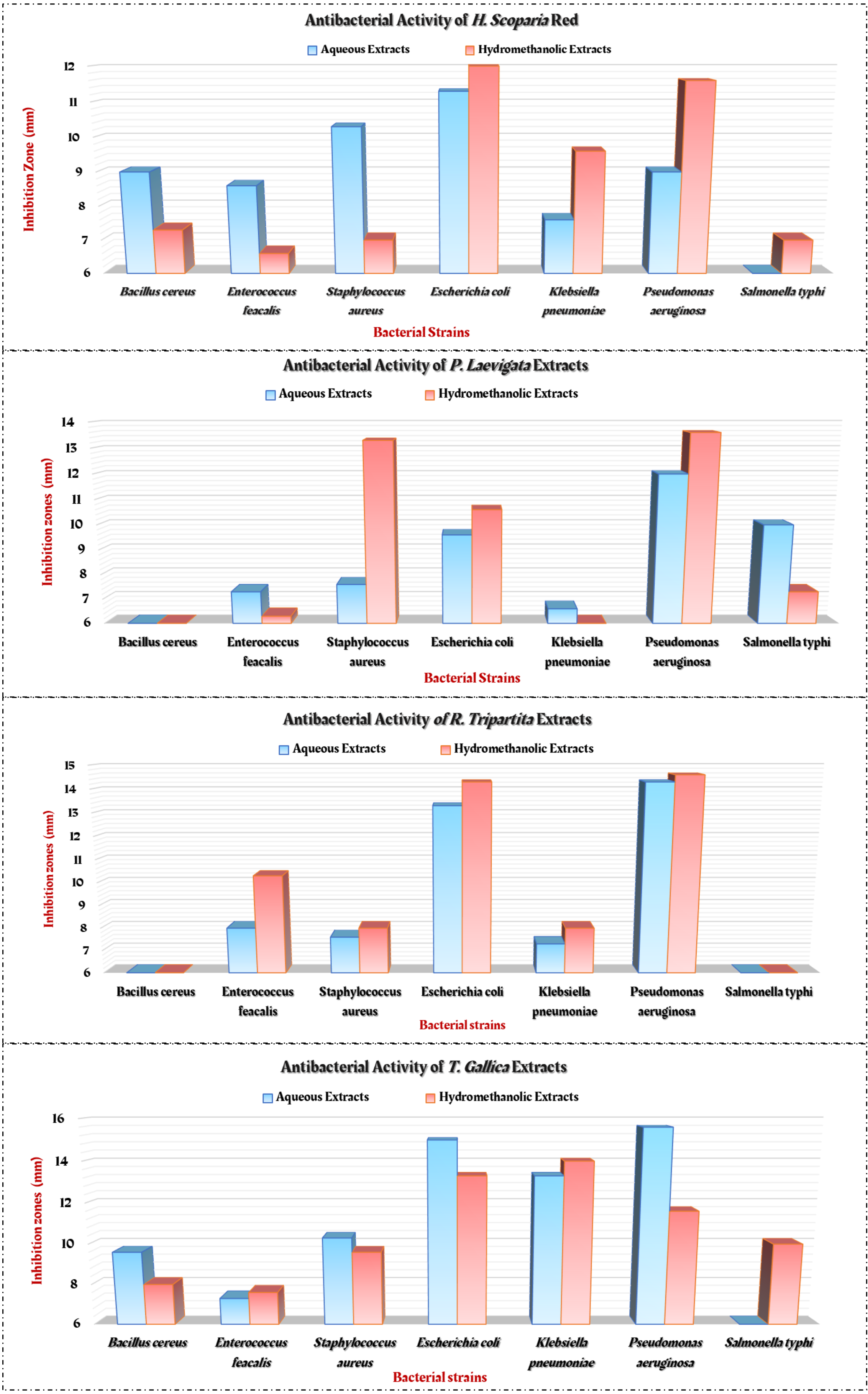


Figure III.37. Antibacterial Activity of Most Active Plant Extracts

The proportion index of antibacterial activity of different plant extracts on pathogenic bacterial strains under investigation was evaluated using the number of positive results obtained for aqueous and hydromethanolic extracts of plant species and total number tests carried out.

As shown in Figure III.38, the proportion index reached its highest value (1), recorded by the aqueous extract of *H. Scoparium* green, followed by the both extracts of *A. schoenanthus*, the Hydromethanolic extracts of the two species of *H. Scoparium*, *T. gallica* and the aqueous extract of *P. laevigata* (0.9 each).

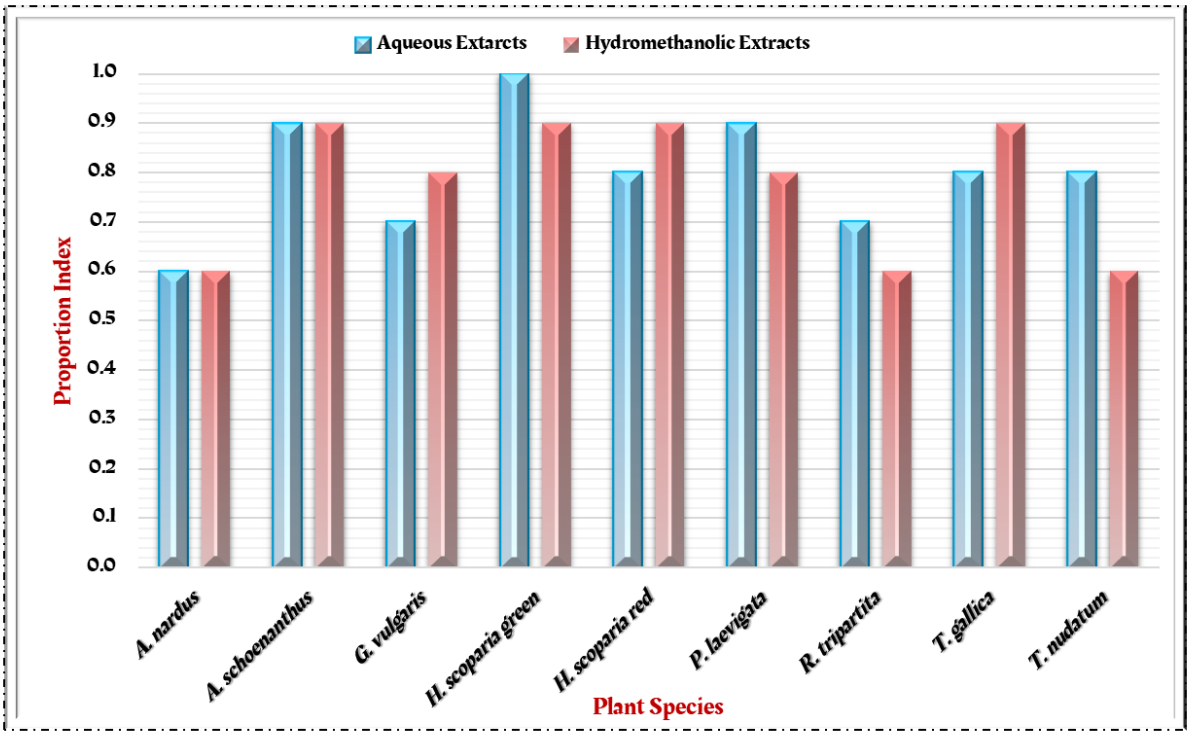


Figure III.38. Proportion Index of Antibacterial Activity

The maximum antibacterial activity was recorded against *Escherichia coli, Klebsiella pneumoniae* and *Staphylococcus aureus* with a maximum inhibition diameter of 15.0±1.4, 14.0±1.0 and 13.3±2.0 mm respectively. Whereas, the lowest antibacterial activity was recorded against the two clinical isolates *Escherichia coli* species with a maximum inhibition diameter of 11.3±0.4 mm.

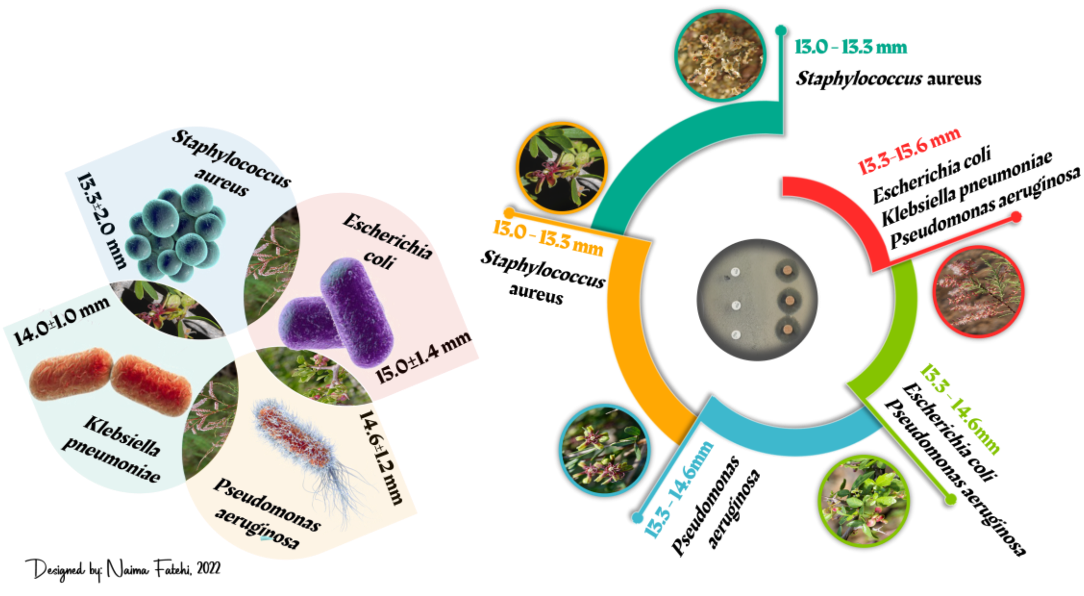


Figure III.39. Maximum Antibacterial Activity Recorded

V.3. Antibiotic Sensitivity Assay

The antibacterial susceptibility pattern of bacterial strains was determined using disc diffusion method. Table III.15 revealed the antibiotic susceptibility pattern of the tested bacteria. As per the results, *Salmonella typhi*, *Klebsiella pneumoniae*, *Bacillus cereus* and *Staphylococcus aureus* showed the maximum susceptibility to antibiotic Ofloxacin, producing inhibition zones of 35.0±0.0, 31.0±2.6, 31.0±1.0, 29.6±0.5 mm respectively. On the contrary, all the tested microorganism (except *Enterococcus faecalis*) were found to be resistant against Fosfomycine and Oxacillin.

Table III.15. Antibacterial Susceptibility Pattern

	Gram Positive Bacteria			Gram Negative Bacteria			
	Bacillus cereus	*Enterococcus feacalis*	*Staphylococcus aureus*	*Escherichia coli*	*Klebsiella pneumoniae*	*Pseudomonas aeruginosa*	*Salmonella typhi*
Ampicillin	11.3±0.5	**21.3±1.1**	10.3±0.5	9.3±0.5	12.0±0.0	6.0±0.0	14.0±1.7
Ofloxacin	**31.0±1.0**	**21.6±0.5**	**29.6±0.5**	**26.3±0.5**	**31.0±2.6**	**24.6±0.5**	**35.0±0.0**
Fosfomycine	6.0±0.0	20.0±0.0	6.0±0.0	6.0±0.0	8.0±0.0	6.0±0.0	6.0±0.0
Cefoxitin	**20.6±0.5**	6.0±0.0	15.6±1.1	12.6±0.5	**20.3±0.5**	6.0±0.0	**27.3±0.5**
Gentamycin	**20.6±1.1**	11.3±1.1	**23.6±1.5**	**25.6±0.5**	**23.0±0.0**	**20.3±1.5**	**25.3±0.5**
Oxacillin	6.0±0.0	6.0±0.0	6.0±0.0	6.0±0.0	7.3±0.5	6.0±0.0	6.0±0.0
Tetracycline	16.6±0.5	9.6±0.5	19.6±0.5	18.3±1.1	20.0±0.0	**26.3±2.3**	20.6±1.1

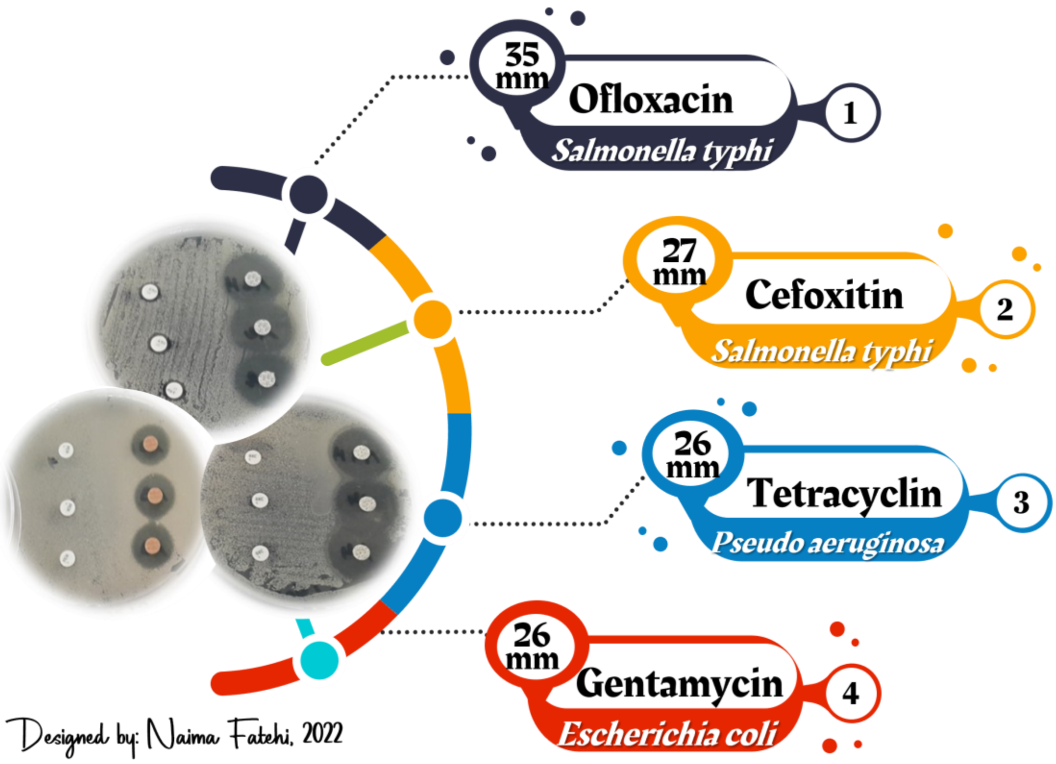


Figure III.40. Antibacterial Susceptibility Pattern

Medicinal plants contain several different phytochemicals or secondary metabolites that may act individually, additively or in synergy to improve health (Srinivasahan and Durairaj, 2014). The different plant extracts have different modes of action for curing diseases (Rubalakshmi et al., 2016). The therapeutic efficacy of plants is because the existence of phytochemicals such as, alkaloids, flavonoids, saponins, terpenoids, steroids, glycosides, tannins, etc. All these secondary metabolites are known for curing one or other diseases.

For instance, Alkaloids are known for antispasmodic, antimalarial, analgesic and diuretic activity. Tannin is reported to exhibit antiviral, antibacterial, antitumor and antimicrobial activities. Terpenoids are reported to have antiviral, anthelmintic, antibacterial, anticancer, antimalarial, anti-inflammatory properties. Saponins are known for anti-inflammatory, antiviral, plant defense and for cholesterol reducing property. Phenols and flavonoids have strong experimental evidence of their inherent ability to modify the body's reaction to allergies, virus and carcinogens. They show antiallergic, anti-inflammatory, antioxidant, anticancer and antimicrobial activities (Moteriya et al., 2015; Padalia and Chanda, 2015; Ram et al., 2015).

In the present study, nine plants which are traditionally used in curing or treating many diseases and disorders were screened for their preliminary antibacterial activity.

The extracts of *H. scoparia* red, *P. laevigata*, *R. tripartita*, and *T. gallica* was found significantly active against the tested bacteria, where the most antibacterial activity was recorded against the gram negative reference strains *Pseudomonas aeruginosa* and *Escherichia coli* with a maximum inhibition diameter of 15.6±0.5 and 15.0±1.4 mm respectively displayed by the aqueous extract of *T. gallica*, followed by the activity detected by the hydromethanolic extract of *R. tripartita* against the gram negative reference strain *Pseudomonas aeruginosa* (14.6±1.2 mm) and the aqueous and hydromethanolic extracts of *R. tripartita* against the gram negative reference strains *Pseudomonas aeruginosa* and *Escherichia coli* with a maximum inhibition diameter of 14.3±2.0 and 14.3±0.5 mm respectively.

Comparing the activity of extracts with reference antibiotics using diffusion method, the extracts of *H. scoparia* red, *P. laevigata*, *R. tripartita*, and *T. gallica* an activity comparable to that of Ampicillin and Cefoxitin. However, the activity of the most plant extracts was higher than that of Fosfomycine and Oxacillin on all the tested microorganism (except *Enterococcus faecalis*).

Some plant extracts were unable to exhibit antibacterial activity against tested bacterial strains. These bacterial strains may have some kind of resistance mechanisms e.g. enzymatic inactivation, target sites modification and decrease intracellular drug accumulation or the concentration of the compound used may not be sufficient (Abeysinghe et al., 2006).

Although, the low values recorded for some plant extracts may be attributed to the fact that the extracts being in crude form, contain very small amounts of bioactive compounds. At the same time, several workers have reported bioactivity of crude extracts of medicinal plants within such range of diameter zone of inhibition (Gupta et al., 2016; Karmegam et al., 2008).

The antibacterial activity of the studied plants varied with different extraction solvents. Aqueous extracts were found to be effective as well as the hydromethanolic extracts. These results were not in accordance to some researchers who had reported that the organic extracts had better antimicrobial activity as compared to aqueous extracts specially against *Escherichia coli, Pseudomonas aeruginosa*, and *Staphylococcus aureus* (Edayadulla and Ramesh, 2012)**.**

The antibacterial action of the aqueous extracts could be attributed to the anionic components such as thiocyanate, nitrate, chlorides and sulfates apart from other water-soluble components which were naturally occurring in the plant material (Al-Daihan et al., 2013; Darout et al., 2000). While the antibacterial activity of the hydromethanolic extracts may be due to the high tendency of the organic solvents to dissolve more organic and active antimicrobial compounds such as phenols and flavonoids (Cowan, 1999)**.**

Knowing the phytochemical profile of different parts and different plants is desirable so that one can decide the part to be explored for any particular activity and it can also help one to decide the part(s) to be chosen for any synergistic evaluation. Knowing the phytochemical profile in the beginning of any experiment is desirable than random selection of the plants (Singh et al., 2017)**.**

The phytochemical analysis of the potent plant extracts of *H. scoparia* red, *P. laevigata, R. tripartita,* and *T. gallica,* confirms the presence of Alkaloids, tannin, flavonoids, phenols, carbohydrate and glycosides in all of them. Phenolic compounds are the potent inhibitors of microbial growth.

Some of these phytochemicals may inhibit the attachment of bacteria on host cell surface membranes and act as potential antiadhesive agents. It has been also reported that the alkaloids and flavonoids are the responsible compounds for antibacterial activity in various plants. Therefore, this high activity of these plants can be attributed to the presence of these phytochemicals that have inhibitory effect on the positive and negative gram bacteria.

Many phytomedicines exert the beneficial effects of plant extracts through the additive or synergistic action of several chemical compounds acting at single or multiple targets and the data from previous study showed that the combination effects of these plants had antibacterial enhancement (additive effects) against most pathogenic bacteria.

VI. *In Vitro* Antifungal Activity

Using Natural products derived from plants as potential antifungal agents are promising, as they have been proven to be able to inhibit the synthesis of fungal cell wall, sphingolipids and protein (Onah, 2020; Phuna et al., 2020; Silva et al., 2020).

Many investigations were carried out to discover plant products that inhibit the fungi like *Aspergillus* sp. and *Penicillium* sp. (Aboody and Mickymaray, 2020; Makhuvele et al., 2020). These two species can produce highly toxic mycotoxins (Aflatoxins and Ochratoxins) that cause common diseases in humans which are difficult to control effectively (Pitt, 1994)**,** Hence, plant products that inhibit their growth without harming the host represent potential therapeutic agent (Loi et al., 2020; Makhuvele et al., 2020).

In the present study, nine different medicinal plants belonging to different families**,** used traditionally by the native people of Bechar region, were collected from different places in Bechar province, and extracted with water and Methanol (80%, v/v), then, their antifungal activities were detected using the radial growth method on solid medium against seven pathogenic fungal strains, isolated from local wheat, toasted and green coffee beans.

VI.1. Detection, Isolation and Identification of Fungal Strains

Wheat and coffee seeds could be attacked by several economically important post-harvest fungal pathogens under storage condition (Pétriacq et al., 2018).

In this study, more than 50 fungal isolates were obtained from the analyses of three investigated samples (local wheat, toasted and green coffee beans) through dilution method. All fungal isolates were obtained in pure cultures by using standard techniques (Figure III.42).

The photomicrographs of all the fungal isolates were taken to help in the identification of the isolates (Figure III.43). The cultural characteristics and the sporulating structures of these isolates are presented in Table III.16 (Guiraud, 1998; Harrigan and McCance, 1976; Oteng-Gyang, 1984)**.**

More than 20 fungal isolates were identified as, *Aspergillus flavus, A. fumigatus, A. militant, A. nidulans, A. niger, A. ochracus, A. terrues, A. ustus, Alternaria* sp., *Cladosporium* sp., *Fusarium* sp., *Penicilium brevicompactum, P. digitatum, P. exponsum, P. italicum, P. oxalicum, P. chrysogenum, Rhizopus* sp. *Ulocladium* sp. The rests of the strains were not identified owing to the lack of sporulating structures under presently used incubation conditions.

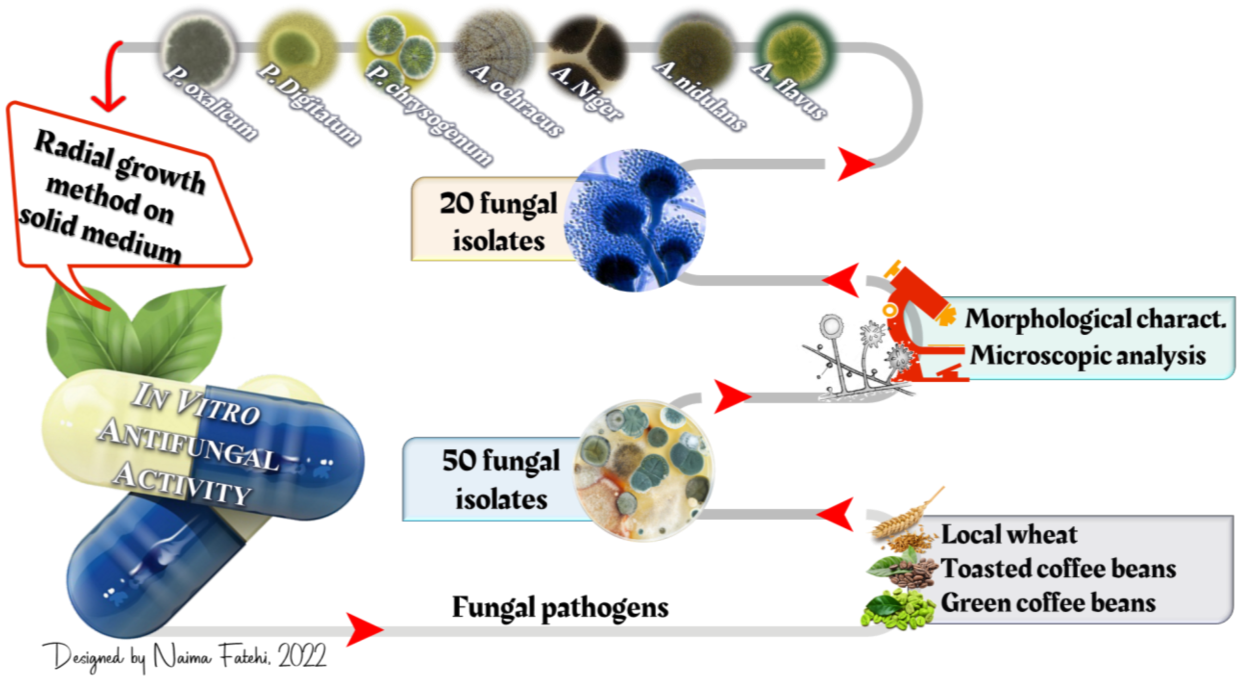


Figure III.41. *In Vitro* Antifungal Activity Procedure

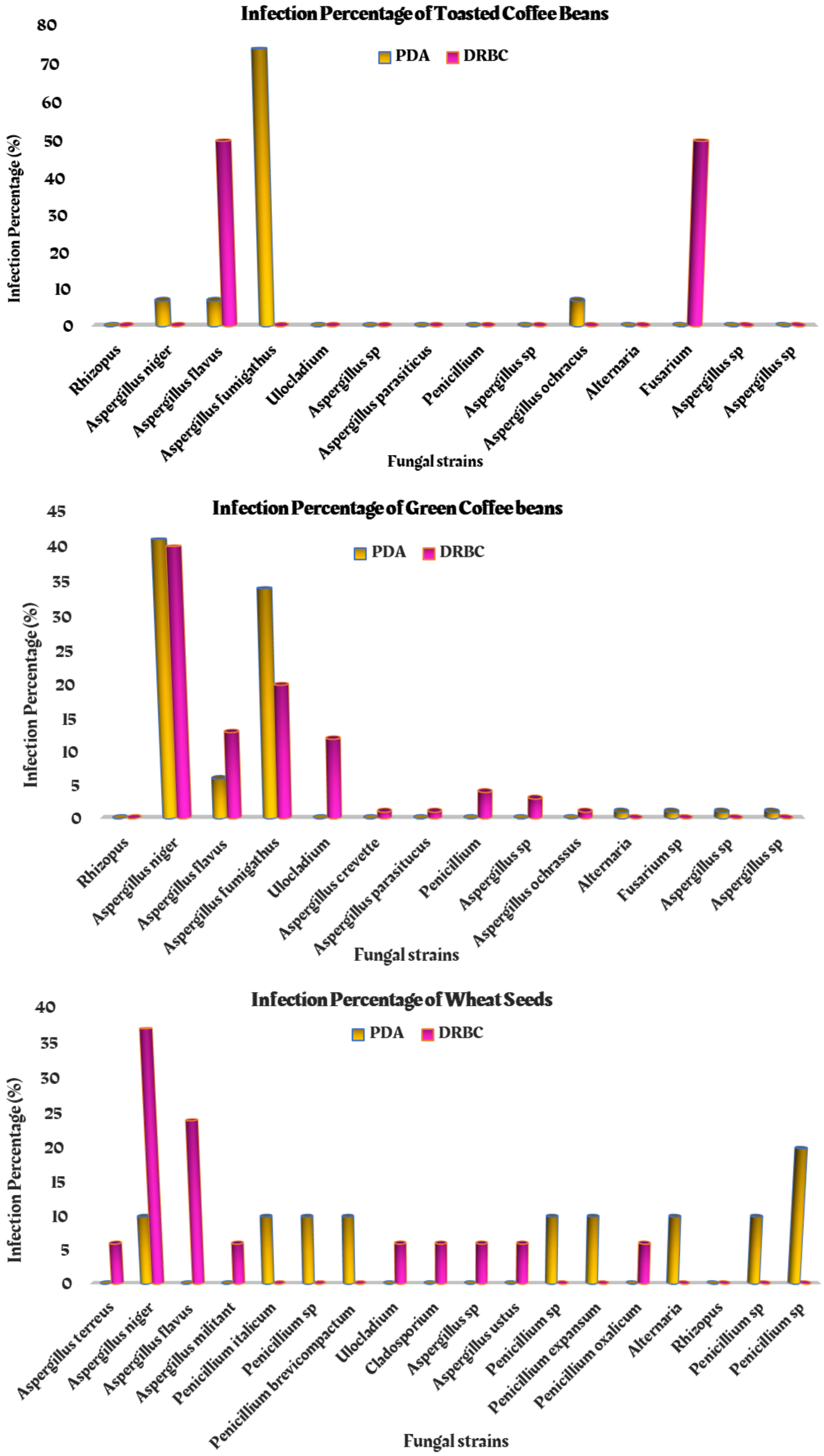


Figure III.42. Infection Percentage of Screened Samples

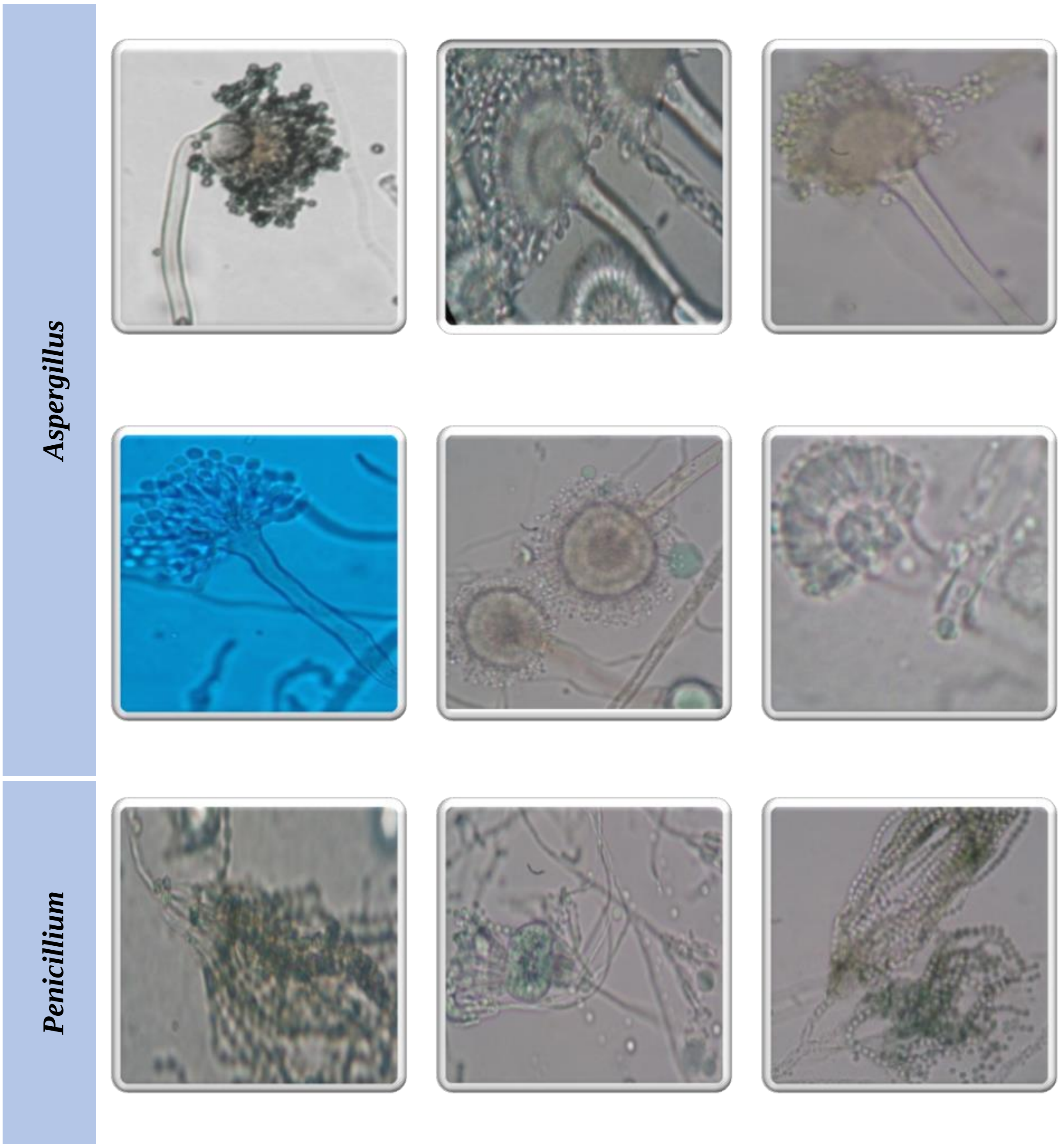
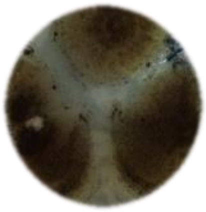
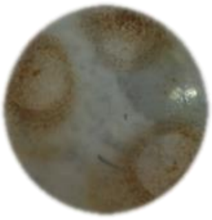
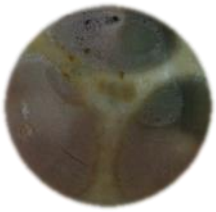
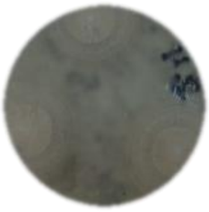
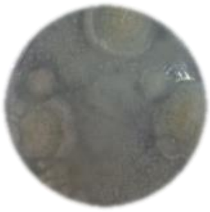
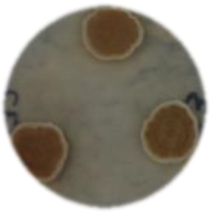
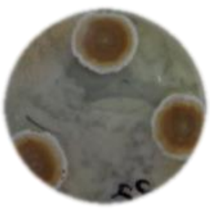
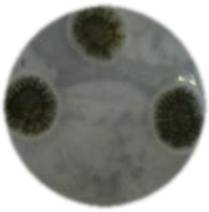
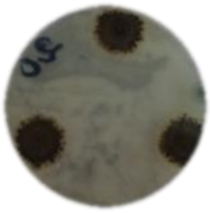


Figure III.43. Photomicrographs of Some Fungal Strains

Table III.16. Identification of Some Fungal Strains According to Pitt (1973), Ramirez (1982), Pitt & Hocking (2009)

	CYA	CDA	MEA
Aspergillus niger			
Aspergillus flavus			
Aspergillus fumigatus			
Aspergillus nidulans			
***Penicillium* chrysogenum**			
Penicillium Digitatum			

VI.2. Antifungal Activity of Plant Extracts

Out of twenty isolated fungus, seven pathogenic strains (*Aspergillus flavus, A. nidulans A. niger, A. ochracus, Penicillium chrysogenum, P. digitatum* and *P. oxalicum*) were used to evaluate the antifungal activity of the selected medicinal plants, calculating the inhibition percentage of mycelial growth of each extract (Table III.17).

The results of the antifungal potency revealed that the hydromethanolic extract of *R. tripartita* and the aqueous extract of *T. nudatum* were the best to suppress the growth of *Aspergillus nidulans* (77 and 66% respectively) compared to the control, followed by the hydromethanolic extract of *H. scoparia* red (63%). The hydromethanolic extracts of *G. alypum, T. nudatum* as well as the aqueous extract of *H. scoparia* green also inhibited *Aspergillus nidulans* growth (60% each).

The aqueous extracts of *A. nardus, G. alypum* and *R. tripartita* suppressed the growth of *Penicillium digitatum* (49, 47 and 43% respectively), whereas the aqueous extract of *T. nudatum* was found to be the best to inhibited the growth of *Penicillium oxalicum* (60%) compared to the other extracts.

Moderate activity was recorded against *Aspergillus niger, Aspergillus ochracus, Penicillium chrysogenum* and *Penicillium oxalicum* exercised by the rest of plants extracts. Less activities were recorded for the hydromethanolic extract of *A. nardus* (0%) and the aqueous extract of *G. alypum* (1%) against *Aspergillus nidulans* and *Aspergillus ochracus* respectively, followed by the low activity recorded by the hydromethanolic extracts of *A. schoenanthus* and *T. nudatum* against *Aspergillus niger* (2% each).

The maximum mycelial growth inhibition was recorded against *Aspergillus nidulans*, which was the most susceptible fungus for all the tested extracts (except for the hydromethanolic extract of *A. nardus*) (Figure III.44).

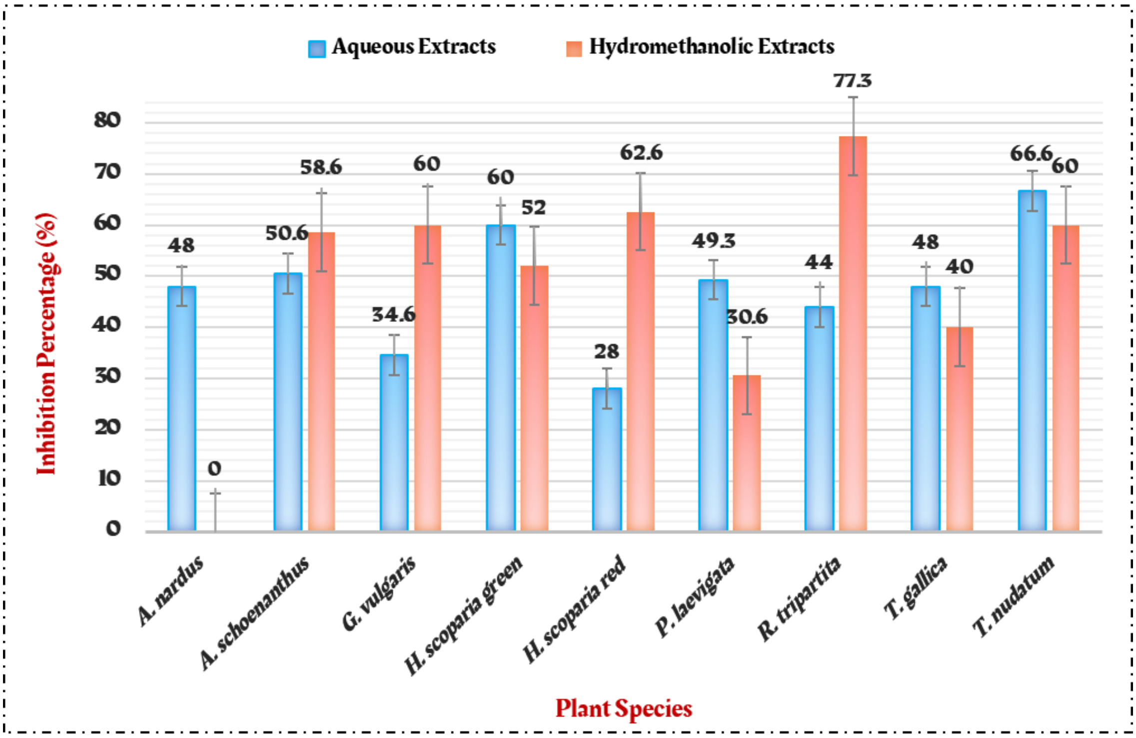


Figure III.44. Mycelial Growth Inhibition of *Aspergillus nidulans*

Plant derived compounds are of interest in this context because they comprise safer or more effective substitutes for synthetically produced antimicrobial agents (Dupuis et al., 1972). Many plant extracts used in folkloric medicine in Algeria were investigated for their antifungal activity and their use to treat pathogenic fungi (Amrouche et al., 2011; Benarba and Meddah, 2014; Bendifallah et al., 2015; Gacem et al., 2013; Lakhdari, 2017; Moghtet et al., 2017; Rahmoun et al., 2014; Tabti et al., 2014; Terfaya et al., 2017).

The extracts of *R. tripartita* and *T. nudatum* showed an excellent activity compared to other plant extracts. All the studied plant extracts have proven to be one of the most important antimicrobial agents successfully used against at least three investigated fungi. The low values recorded for some plant extracts may be attributed to the fact that the extracts being in crude form, contain very small amounts of bioactive compounds.

Table III.17. Antifungal Inhibitory Activity of Plant Extracts

		A. nardus	*A. schoenanthus*	*G. alypum*	*H. scoparia* green	*H. scoparia* red	*P. laevigata*	*R. tripartita*	*T. gallica*	*T. nudatum*
		Mycelial Growth Inhibition (%)								
Aspergillus flavus	**Aq. Ext**	26.6±0.5	9.0±0.0	13.3±1.1	19.0±6.3	24.8±1.1	20.0±3.4	21.2±2.8	**45.4±0.0**	23.0±0.0
	Hm. Ext	**36.3±4.3**	9.0±2.0	24.8±2.3	9.0±5.2	9.6±2.5	22.7±3.5	**50.3±2.5**	18.1±3.0	10.9±0.0
Aspergillus nidulans	**Aq. Ext**	**48.0±1.4**	**50.6±2.3**	34.6±4.5	**60.0±0.0**	28.0±3.6	**49.3±2.0**	**44.0±0.0**	**48.0±1.7**	**66.6±1.5**
	Hm. Ext	0.0±4.0	**58.6±0.5**	**60.0±0.0**	**52.0±2.8**	**62.6±1.1**	**30.6±3.6**	**77.3±1.1**	40.0±0.0	**60.0±0.0**
Aspergillus niger	**Aq. Ext**	13.7±4.1	17.4±2.8	10.6±1.5	4.9±1.1	16.5±0.7	18.1±3.5	7.4±4.0	11.8±4.3	22.5±2.3
	Hm. Ext	18.7±5.1	2.0±4.9	21.2±4.8	23.7±3.7	23.7±1.1	23.1±1.7	19.9±7.0	4.3±3.0	2.4±2.0
Aspergillus ochracus	**Aq. Ext**	16.6±3.0	9.0±1.5	0.6±2.3	5.5±0.5	17.3±4.0	20.1±2.8	7.6±1.1	27.7±4.5	6.9±0.5
	Hm. Ext	**40.9±2.8**	20.8±2.6	11.8±2.5	29.1±4.9	4.1±2.6	6.9±0.5	4.8±2.0	6.9±0.5	4.1±1.0
Penicillium chrysogenum	**Aq. Ext**	18.9±0.0	25.6±2.8	39.1±0.0	22.9±3.6	29.7±2.5	18.9±0.0	18.9±0.0	25.6±2.8	22.9±1.4
	Hm. Ext	**39.1±0.0**	21.6±1.1	**39.1±0.0**	32.4±2.8	22.9±1.7	29.0±3.5	**32.4±2.8**	**32.4±2.8**	25.6±2.8
Penicillium digitatum	**Aq. Ext**	**48.7±4.6**	1.8±2.5	**45.6±1.0**	13.1±4.3	6.2±4.0	14.3±4.0	**42.5±3.5**	**34.3±3.0**	21.2±2.7
	Hm. Ext	11.8±2.6	15.6±5.0	21.8±2.8	14.3±1.1	8.1±1.4	10.9±3.5	10.9±3.5	15.6±0.0	15.6±2.0
Penicillium oxalicum	**Aq. Ext**	11.7±0.0	**32.3±4.3**	26.4±1.5	14.7±1.1	22.7±2.1	**36.7±3.1**	**36.7±1.1**	11.7±0.0	**60.2±1.7**
	Hm. Ext	**36.7±1.1**	**42.6±0.0**	**35.2±3.7**	19.1±1.1	19.1±1.5	**36.7±1.1**	11.7±0.0	7.3±0.0	22.0±2.5

Aq. Ext: Aqueous Extract **Hm. Ext**: Hydromethanolic Extract

Secondary metabolites produced by plants possess several interesting biological activities, and are a source of pharmacologically active principles against pathogenic microorganisms. Useful antimicrobial phytochemicals, such as phenolics, flavonoids, tannins, coumarins, terpenoids and alkaloids plus other compounds, are abundantly found in the plant species used in this study, and they may be responsible for this significant activity against the tested fungi(Aboody and Mickymaray, 2020; Loi et al., 2020; Onah, 2020).

Several studies have been conducted to understand the mechanism of action of plant extracts; however, it is still unclear. Possible action mechanisms by which mycelial growth may be reduced or totally inhibited have been proposed (Cristani et al., 2007; Lucini et al., 2006; Omidbeygi et al., 2007; Sharma and Tripathi, 2006; Veldhuizen et al., 2006).

Several researchers suggested that the mechanism of actions may include enzyme inhibition by the oxidized compounds, and act as a source of stable free radical and often leading to inactivation of the protein and loss of function. They have the ability to complex with extracellular and soluble proteins and to complex with microbial cell walls and disrupt microbial membranes (Aboody and Mickymaray, 2020; Mishra et al., 2009; Onah, 2020)**,** some have ability to intercalate with DNA, formation of ion channels in the microbial membrane, competitive inhibition of adhesion of microbial proteins to host polysaccharide receptors (Cowan, 1999)**.** It is also commonly accepted that it is the toxic effects of some phytochemical components and extracts on the functionality and structure of the cell membrane that is responsible for the aforesaid activity (Loi et al., 2020; Onah, 2020; Sikkema et al., 1995)**.**

The different results obtained using several species as bio-fungicides extracts suggests that there are many substances, which can still be exploited for the management of pathogens. These substances can be further subjected to isolation of the therapeutic antimicrobials and carry out further pharmacological evaluation to resolve the problems of fungal pathogens (Abayhne and Chauhan, 2016)**.**

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General Conclusion

The rich biodiversity of plants makes them a treasure house for obtaining new and novel compounds either themselves as drugs or lead molecules for drugs with a different mechanism of action.

An Ethnobotanical Survey of Medicinal Plants from Bechar Region, as well as phytochemicals, antioxidant, antibacterial, and antifungal studies of nine folkloric medicinal plants, widely used in traditional medicine in southwest Algeria, are being actively conducted in this work.

The Ethnobotanical Survey was undertaken to collect detailed information about the usage of plants in human therapy in the Bechar region (south-western Algeria). The information has been documented by interviewing a total of 250 traditional herbalists and traditional health practitioners, following different ethnobotanical methods. A total of 162 plant species representing 143 genera and 50 families were used in the treatment of various diseases. The most encountered medicinal plant families were Asteraceae (18 spp.), Apiaceae & Lamiaceae (12 spp. each), Fabaceae (10 spp.), Brassicaceae, Chenopodiaceae & Poaceae (9 spp. each). Plant leaves were the most commonly used plant part, and decoction and cataplasm were the most common methods of traditional drug preparation.

The survey shows that there is a high diversity of medicinal plants used in the Bechar region for treating common ailments and some very important diseases including COVID-19. The preservation of this traditional knowledge is an essential requirement for maintaining continuity and transmission of traditional medicine, and as previously mentioned for recording traditional cultural heritage also based on local biodiversity which risks being lost.

The complete exploration of medicinal plants of this area will help to maximize the utility of pharmaceutical products, particularly from plants whose uses are not documented yet. Extensive ethnobotanical surveys may help identify suitable sources of medicinal flora, and ultimately bring them into domestication.

The assessment of phytochemical content and antioxidant potency of the crude aqueous and hydromethanolic extracts of a nine-folkloric medicinal plant from the

Bechar region, namely: *A. nardus*, *A. schoenanthus*, *G. alypum*, two species of *H. scoparia* green & red, *P. laevigata*, *R. tripartita*, *T. gallica*, and *T. nudatum*, was conducted.

Screening for major classes of phytochemicals was done using standard chemical tests. Whereas, the Folin-Ciocalteu assay was conducted to quantify the total phenolic content, the aluminum chloride colorimetric method was used to quantify the total flavonoid content and the phenol-sulfuric acid method was conducted to quantify the total polysaccharide content. The antioxidant activity was performed by three methods: DPPH, FRAP, and TAC.

Among all extracts, the aqueous extract of *R. tripartita* (276.221±0.079 mg GAE/g) and the hydromethanolic extracts of *P. laevigata* and *H. scoparia* red (245.095±0.037 and 243.609±0.231 mg GAE/g respectively) showed the highest phenolic content. The hydromethanolic extracts of *P. laevigata*, *R. tripartita*, and *G. alypum* showed the highest flavonoids content (646.531±0.234, 510.531±0.023, and 494.197±0.077 mg QE/g respectively), whereas, the hydromethanolic extracts of *A. schoenanthus*, *R. tripartita*, and *H. scoparia* green showed the highest polysaccharide content (356.609±0.005, 350.440±0.049 and 344.957±0.046 mg GE/g respectively).

A polyphenol investigation using HPLC was also carried out in the two hydromethanolic extracts of *P. laevigata* and *R. tripartita*, where, the major identified compounds found in these two species were: Naringenin, Ferulic acid, followed by p-coumaric acid and caffeic acid in a smaller amount.

The antioxidant activity performed by DPPH, FRAP, and TAC shows that the hydromethanolic extracts had a strong radical scavenging ability compared with the aqueous extracts. The hydromethanolic and aqueous extracts of *R. tripartita* exhibited the higher total antioxidant activity with a very low IC_{50} (15.838 and 19.539 mg/mL respectively). The hydromethanolic extracts of *R. tripartita*, *P. laevigata*, *T. gallica*, and *H. scoparia* red had the highest ferric reducing antioxidant potency (624.194±0.294, 589.195±0.054, 470.423±0.141, and 436.914±0.153 AAEFRAP/g respectively). Whereas, the aqueous and hydromethanolic extracts of *R. tripartita* (426.581±0.1812 and 361.507±0.326 mg AAE/g respectively) and the hydromethanolic extracts of *T. gallica*, *H. scoparia* red, and *P. laevigata* (295.166±0.165, 289.673±0.051, and 264.108±0.170 mg AAE/g respectively) had the highest total antioxidant capacity.

G. alypum, H. scoparia red*, P. laevigata, R. tripartita, and T. gallica* species exhibited noticeable antioxidant activities, thus representing promising sources of plant-based medicine. The strong antioxidant properties of these plants highly correlate with the presence of phenolic and flavonoid compounds in appreciable amounts, supporting their uses in traditional medicine. However, further investigation is required to correlate the antioxidant activity and polyphenol contents and to clarify the mechanism of plant phenolic action *in vivo.*

The antibacterial activities of different extracts were evaluated by using disc diffusion method agar and antibiotics susceptibility of ten selected microorganisms: seven reference strains, *Bacillus cereus*, *Enterococcus faecalis*, *Staphylococcus aureus*, *Escherichia coli*, *Klebsiella pneumoniae*, *Pseudomonas aeruginosa*, *Salmonella typhi*, and three clinically isolated strains, *Escherichia coli* (Urinary Tract Infection), *Escherichia coli* (Vaginal Infection) and *Staphylococcus aureus* (Skin Infection).

The maximum antibacterial activity was recorded against the gram-negative reference strains *Pseudomonas aeruginosa* and *Escherichia coli* with a maximum inhibition diameter of 15.6±0.5 and 15.0±1.4 mm respectively displayed by the aqueous extract of *T. gallica*, followed by the activity detected by the hydromethanolic extract of *R. tripartita* against the gram-negative reference strain *Pseudomonas aeruginosa* (14.6±1.2 mm) and the aqueous and hydromethanolic extracts of *R. tripartita* against the gram-negative reference strain *Pseudomonas aeruginosa* and *Escherichia coli* with a maximum inhibition diameter of 14.3±2.0 and 14.3±0.5 mm respectively.

According to the present study, *H. scoparia red, P. laevigata, R. tripartita, and T. gallica* can be served as a broad-spectrum antibiotic and used as a potent source of natural antibacterial agents by replacing commercially available synthetic drugs that may have a large number of side effects.

The antifungal activity was evaluated using the radial growth method on a solid medium, against seven fungal pathogens isolated from local wheat, toasted and green Coffee beans.

The results revealed that the hydromethanolic extract of *R. tripartita* and the aqueous extract of *T. nudatum* were the best to suppress the growth of *Aspergillus nidulans* (77 and 66% respectively), followed by the hydromethanolic extract of *H. scoparia* red (63%). The hydromethanolic extracts of *G. vulgaris*, *T. nudatum* as well as the aqueous extract of *H. scoparia* green also inhibited *Aspergillus nidulans* growth (60% each), whereas the aqueous extract of *T. nudatum* was found to be the best to inhibit the growth of *Penicillium oxalicum* (60%) compared to the other extracts. Fewer activities were recorded for the hydromethanolic extract of *A. nardus* (0%) and the aqueous extract of *G. vulgaris* (1%) against *Aspergillus nidulans* and *Aspergillus ochracus* respectively. However, further studies are needed to determine the antifungal compounds in such plant extracts as well as their formulation to be applied as alternative methods to be used in the treatment of fungal diseases.

The ultimate conclusion of this study suggests that great attention should be paid to the therapeutic potency of some plants used in traditional medicine, which are found to have plenty of pharmacological properties that could be sufficiently better when considering a natural food and feed additives to improve human health.

Further studies are needed to determine the bioactive compounds in such plant extracts (isolation, separation, and identification) as well as their formulation to be applied as alternative methods to be used in the treatment of various diseases.