

# Pharmacology, taxonomy and phytochemistry of the genus *Artemisia* specifically from Pakistan: a comprehensive review

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## ABSTRACT

The genus *Artemisia* belongs to family Asteraceae and commonly used for ailments of multiple lethal diseases. Twenty-nine species of the genus have been identified from Pakistan which are widely used as pharmaceutical, agricultural, cosmetics, sanitary, perfumes and food industries. In this review we studied the medicinal uses, taxonomy, essential oils as well as phytochemistry were compiled. Data was collected from the original research articles, texts books and review papers including globally accepted search engines i.e. PubMed, ScienceDirect, Scopus, Google Scholar and Web of Science. Species found of *Artemisia* in Pakistan with their medicinal properties and phytochemicals were recorded. The present review highlights the geographical distribution, morphological features and medicinal importance of different *Artemisia* species. Species of the genus are used in different traditional treatments by the local communities of Pakistan and worldwide. The essential oils and some other important derivatives such as artemisinin are commonly used to cure malaria, cancer, stomach, kidney, liver, and spleen other bacterial, fungal, helminthic diseases and much more. These species also possess some important extract such as lignans, polyphenols and flavonoids that help in activation of certain pathways. Majority of work on the taxonomic validation of the species are showing confusion in its morphology, for the correct identification of the species in the present review special focus has been made on its morphological characteristics, along with their traditional uses, pharmacology and phytochemical constituents. This review will provide baseline information for further research on the genus and as well as at species level on different aspects. The aim of this study is to provide comprehensive overview of Genus *Artemisia* specifically the species of the genus from Pakistan.

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## Introduction

The Genus *Artemisia* is large and diverse genus belongs to the tribe Anthemideae of the family Asteraceae (Compositae) comprising hardy herbs and shrubs mostly covered with hairs (1). It consist more than 500 species (2). In Pakistan, this genus comprises of 25 well known species. This genus is wind pollinated and cosmopolitan mainly grow in dry and semi dry habitats. Species of the genus is predominantly growing in temperate areas of northern hemisphere but few species have been reported from southern hemisphere (3). However its center of diversification is Central Asia; representing about 150 species in China, 50 species in Japan and 35 species in Iran, while the speciation areas are North West America, Irano-Turanian, 29 species in flora of Pakistan and Mediterranean region (4). Few species have been reported from Africa and Europe (5). Among these species, only 10 species of this genus act as annual or biennials, while most of the species are perennial plants (1). Some of the *Artemisia* species produce essential oils which are used in medicines, perfumes, cosmetics, and pharmaceutical industry and are composed of monoterpenoids having chrysanthenol, chrysanthenone,

$\alpha/\beta$ -thujones, 1,8-cineole and camphor as major components (11). The chemical composition of these oils is different from specie to specie depend on the environmental conditions (12) some of species of this genus are economically important and used as medicines, as a food, as soil stabilizers and also have ornamental uses while some are allergenic or poisonous, while others are intrusive which are inauspicious to crop yield (13).

Some species of the genus *Artemisia* are used for the treatment of high blood pressure, diabetes and gastrointestinal disorders (14). Artemisinin which is extracted from *Artemisia annua* is used to treat malaria, fever and also for treatment of different types of cancer (15). According to Yao, Chen (16) the species is used in anti-bacterial, anti-fungal, anti-inflammation, anti-tumor and anti-pathogenic activities and also used for treatment of hepatitis, ulcer and hyperlipidemia. It is also effective in treatment of leishmaniasis (17). Despite the above mentioned uses the plant extracts are also used for Asthma, skin diseases, constipation and also enhance the digestion in stomach (18). These extracts also have

neurological activities in order to treat epilepsy, Alzheimer's disease (19).

Plants and their products have been screened for health purposes, because a great number of people has been indulged openly or ramblingly in the traditional usage of different products from plant origin. Among the numerous herbs used in modern medicine, many species of the genus *Artemisia* are also included. In this review we described distribution of genus *Artemisia* in Pakistan, highlighted and summarized medicinal role of *Artemisia* species and covered taxonomy, antimicrobial, insecticidal and antioxidant activities of *Artemisia* species. In present work, role of essential oil and its composition also studied in detail. We also try to deliver an understanding on different species of the genus *Artemisia* with extraordinary attention on their pharmacological potentials and phytochemistry.

### Methodology

Different search engines were searched for the compilation of data on genus *Artemisia* like, Scopus, Google Scholar, PubMed, Science Direct, Web of Science, Medline and Research Gate. Using various indicators like, *Artemisia*, ethnobotany, ethnopharmacology, taxonomy, morphology, traditional uses, toxicology and phytochemistry were used for searching the literature. For the correct taxonomic names and synonyms, species name were verified from database (<http://www.theplantlist.org/>), and (<http://www.ipni.org/>). Ethnomedicinal uses searched in different literature and crossed checked from accessible published and unpublished data such as thesis of different universities, and research centers of Pakistan (<http://eprints.hec.gov.pk/>), Indian online theses (<http://shodhganga.inflibnet.ac.in/>), Nepal (<http://tribhuvan.university.edu.np/tucentral-library.tucl/>) and China (<http://www.cnki.net/>). Online flora of Pakistan has been searched for plant description (<http://www.eflora.org/>). In addition to this, more than 109 research articles were studied, published in different research journals on the ethno-botany/ethnopharmacology. Mostly the data have been taken from google scholar and science direct. Scientifically accepted program ChemDraw were used for drawing the chemical formula for bioactive compounds. The above mentioned online search engines were used for the confirmation and validity of the taxonomic names, distribution and their correct identification.

### Taxonomy

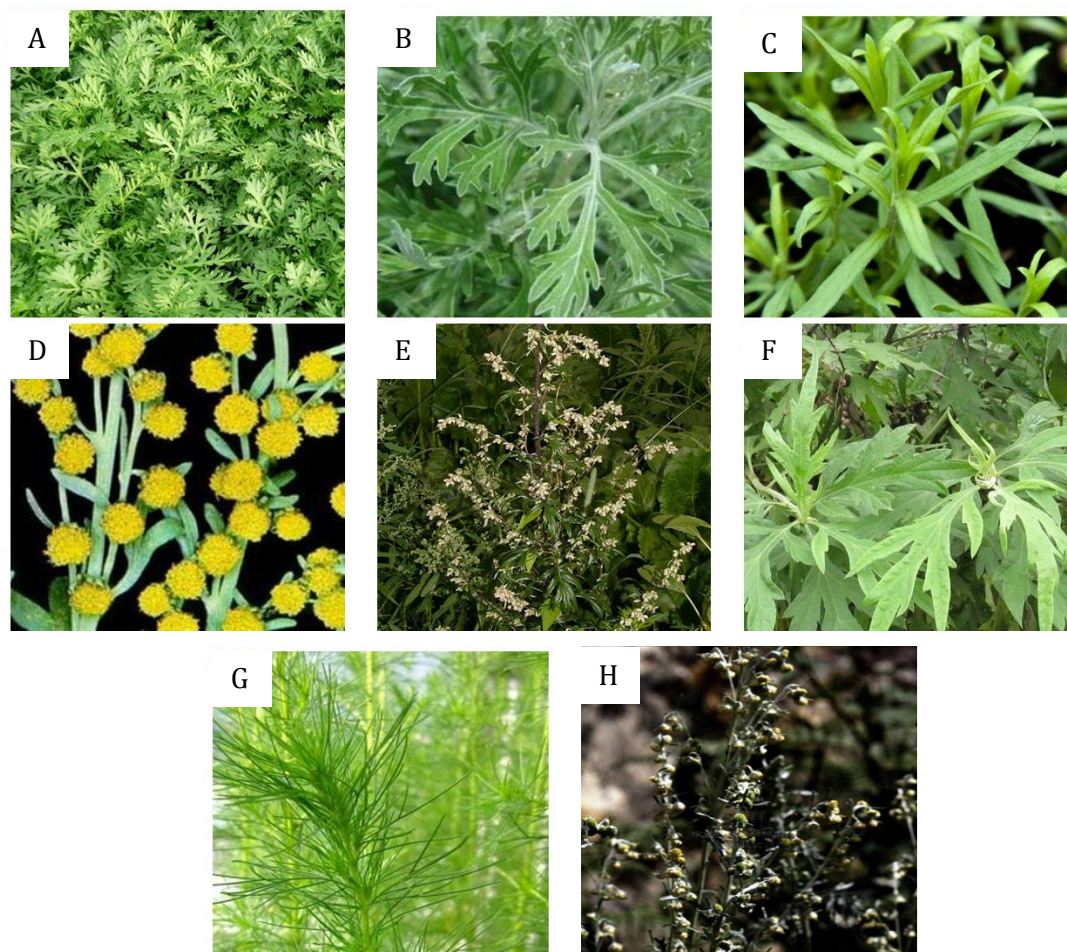
The taxonomic characteristics of the genus *Artemisia* revealed that the leaves are of different sizes, shapes and textures. These are alternate and pinnatifid to pinnatisect. The Inflorescence capitulum are small, mostly ellipsoid to ovate, arranged in form of Paniculate Racemose and contain florets which are tubular, inserted on receptacle covered by involucre bracts, present in few rows. The corollas are of white, green, yellow,

purplish or sometimes brown color (6). The shape of cypselas may be oblique or terminal, corolla scar, elliptical, spheroidal, ovate or compressed. Its color varies from light brown to dark brown, surface may be glabrous and sometimes deeply or finely striates. The size of cypselas is 0.5-1.5×0.25-0.75mm (7). Many of the species belonging to this genus start flowering at the end of summer or during winter (8). As far as the morphological characters of the species is concerned, most of species have different morphological forms while some are closely resemble with each other that's why its systematic classification of genus *Artemisia* has been considered to be very difficult (9). Still conflicts between traditional and molecular data need to be resolved (10). The different morphological feature of some important *Artemisia* species is given in Figure 1.

The genus *Artemisia* is a large diverse genus of about 500 species belong to family Asteraceae. Various common names are used for the species of the genus such as mugwort, sagebrush and wormwood (20). The genus has most of the herbaceous species and rarely shrubs, these species are well known for their powerful chemical compounds and essential oils used for various disorder (21). Name of *Artemisia* derives from the Greek goddess Artemis, the Greek Queens Artemisia (Oxford English Dictionary, 6<sup>th</sup> ed.). Plant of the genus are biennial or perennial, commonly bitter aromatic, glabrous, punctate-glandulose or hairy, herb or small shrubs, tap root horizontal rootstock. Alternate leaves, petiolate and basal large, often sessile to subsessile, toothed-shallowly to undivided, palmate or pinnatifid, 2-4 pinnatisect. Synflorescence a panicle, sometime recemoid or spicate. Capitula numerous, rarely mediocre, erect or nodding, ovate or oblong cylindrical. Involucre ovoid to campanulate or hemispherical, Phyllaries in 2-4 series sometime 6, imbricate, hairy or glabrous, scarious margined or scarious, Flower brownish, yellowish or reddish, all tubular. Ray florets, pistillate, fertile, narrowly tubular corolla, generally tapering upwards 2-4 toothed. Disc florets bisexual, fertile or sterile, tubular corolla, funnel shaped or campanulate, 5 toothed, oblong anthers, and longer than filaments, obtuse or cordate at the base, apical appendages lanceolate, style exerted. Cypselas of both marginal and discs terete, oblong ellipsoid or obovoid nearly fusiform prismatic, faintly many striate sometime smooth. Pappus absent or usually cypselas with minute annulus or scarious corolliform ring.

### Ethnopharmacology of genus *Artemisia*

Genus *Artemisia* harbours economically important plant species which are used since from long time in pharmacology and various culinary purposes. Different biopharmaceutical products available in the market containing *Artemisia* extracts are used for the ailment of certain disorders. Different ancient medicinal plants systems are available from long time to treat different disease including; Siddha, Ayurveda,



**Figure 1** Morphological features of different artemisia species **(A)** *Artemisia annua* **(B)** *Artemisia amygdalina* **(C)** *Artemisia dracunculus* **(D)** *Artemisia absinthium* **(E)** *Artemisia vulgaris* **(F)** *Artemisia dubia* **(G)** *Artemisia scoparia* **(H)** *Artemisia roxburghiana*

Buddha, and Traditional Chinese Medicines (TCM) (72; 106).

*Artemisia abyssinica* is used as antibacterial, antispasmodic, antirheumatic and anthelmintic agent. This plant is mostly grown in Saudi Arabia and its local name is "ather" (22). In addition, *Artemisia absinthium* (wormwood) used to treat indigestion and anorexia and has also antiparasitic effect. It is also used in gastric herbal preparations and in alcoholic beverages (23).

Among other species *Artemisia biennis* is used as antiseptics and spices. It is used to treat wounds, inflammation and chest infections. Whole plant and seeds are used in the treatment of stomach cramps, painful menstruation. Externally it have been used for treating wounds and sores (24). *Artemisia argyi* mainly grow in China (locally known as ai ye) and Japan (locally known as gaiyou) and is used in herbal medicines for treatment of kidney, liver and spleen (25). *Artemisia arborescens* (great mugwort) is morphologically fluctuating species having grey green to silver leaves and is used as an anti-inflammatory drug (26). As for as the

distribution, of *Artemisia campestris* L. is faintly aromatic herb, mostly found in Tunisia and its local name is "tgouft". This plant has anti-rheumatic, anti-inflammatory, anti-venin and anti-bacterial activities (27). *Artemisia annua* is used in Chinese folk medicines for the ailment of malaria and chills.

Decoctions of *Artemisia herba-alba* (*Artemisia brevifolia* Wall., *Artemisia merittima* L. ) is used in traditional medicines to treat fever and nervous problems (17) while, *Artemisia iwayomogi* is used for treatment liver diseases. The extraction of leaves of *Artemisia ludoviciana* is used as an antidiarrheal drug) and *Artemisia princeps* (Japanese mugwort or yomogi) is used in traditional medicines to treat many circulatory disorders, diarrhea and inflammation (28). Among other species *Artemisia judaica* L. is perennial shrub mostly used as anthelmintic drug while, *Artemisia nilagirica* (Indian wormwood) is used as insecticides (29). The aerial parts of *Artemisia scoparia* (redstem wormwood) produce essential oils that is used as anti-bacterial, anti-pyretic, anti-septic, anti-cholesterolemic, insecticidal,

purgative, diuretic, gall bladder inflammation and liver diseases including hepatitis and jaundice (30).

## Phytochemistry

### Terpenes

The genus *Artemisia* has great potential for yielding essential oils which are natural, volatile and complex compounds having strong aroma. The chemical composition of essential oils is very complex containing about 20-60 components at different concentration. However, it is noteworthy that 2-3 major components which determine the biological activities of essential oils, included two groups: one is composed of terpenes, which is the main group while the other group has aromatic and aliphatic components. The aromatic aroma of some species of genus *Artemisia* is due to the presence of high concentration of terpenes, particularly in flowers and leaves (28).

### Proteins and polysaccharides

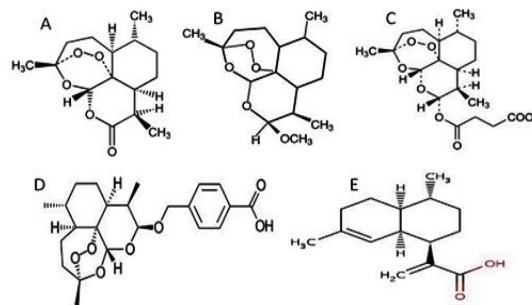
It has been reported that nowadays approximately 3,000 essential oils have known in which 300 are commercially important and is used in pharmaceutical, agricultural, cosmetics, sanitary, perfumes and food industries. Lipophilic components of essential oils, when inhaled or applied topically, inhibit the microbial growth by interacting with lipid portion of cell membranes of microbes and make it permeable due to which death of microbial cell occur. The essential oil also restrains the synthesis of DNA, RNA, proteins and polysaccharides in microbial cells (28).

### Artemisinin: An important phytochemical

Artemisinin is one of important secondary metabolite produced by plants of family Asteraceae and used for the treatment of malaria. About 25 species of *Artemisia* are found and growing in Pakistan, and can be used for the treatment of malaria as they produces artemisinin (71). It is also reported that artemisinin can be used in certain other disease treatments, like very effective against certain other parasites like Leishmania (41), toxoplasma (72), schistosoma (73), trypanosome (74). In addition, the artemisinin can be used in the treatment of certain hazardous and incurable diseases, like it can be used in the treatment of hepatitis B (75). It is also use in the treatment of wide range of cancers like human leukemia, colon cancer, small-cell lung carcinomas and breast cancer (76).

The common name of artemisinin is "qinghaosu", and it is a sesquiterpene lactone endoperoxide. Various derivatives like artemether, artesunic acid and artelinic acid can also be synthetically produced based on the natural product artemisinin isolated from plants (Fig. 2). These synthetic derivatives are very effective against malaria caused by multi-drug resistant plasmodium falciparum (77).

Artemisinin is reported to be found only in leaves and flowers of the plant at very minute concentration, and its



**Figure 2** Artemisinin and its semi-synthetic derivatives, which are currently, used in the treatment of malaria (A) Artemisinin (B) Artemether (C) Artesunic acid (D) Artelinic acid (E) Artemisinic acid.

dry weight ranges from 0.01-0.8% (78). Many methods can be used to enhance the production of artemisinin, thus to produce it in large concentration and to make them easily available to all people throughout the world. One method reported to enhance its production is, high artemisinin producing lines and breeding selection and to determine the environmental condition which better suits the plant growth and can leads to an improvement in the content of artemisinin (79). Another method to increase artemisinin production in *Artemisia annua* is biotechnological approach. Several genes are responsible for artemisinin production, and genetic variability is linked to the content of artemisinin, so by targeting these artemisinin genes can leads to improvement in artemisinin content (80).

### Other important phytochemicals

The major components of essential oils of four *Artemisia* species; *A. dracuncululus*, *A. santonicum*, *A. absinthium* and *A. spicigera* are camphor, cineole, caryophyllene oxide, chamazulene, nuciferol propionate, nuciferol butanoate, borneol, cubenol,  $\alpha$ -terpineol spathulenol,  $\beta$ -eudesmol and terpinen-4-ol (31). The essential oil of *A. absinthium* is also effective against human pathogens for example; *Pseudomonas aeruginosa*, *Staphylococcus aureus*, *Escherichia coli*, *Klebsiella pneumoniae* and *Salmonella enteritidis* (32). Another specie of *Artemisia*; *A. scoparia* in which 32 compounds are recognized that is 98% of the total composition. The major components of essential oil from *A. scoparia* are capillene, diacetylenes 1-phenyl-2,4-pentadiyne,  $\alpha$ -pinene,  $\beta$ -pinene, methyl eugenol, myrcene, limonene and  $\beta$ -ocimene reported by Joshi, Padalia, Mathela (33). Borneol and bornyl acetate are the main constituents of essential oil of *A. argyi* (34). The main components of essential oil of *A. rubripes* are camphor, germacrene D, 1,8-cineole and  $\beta$ -caryophyllene (35). *Artemisia ordosica* which is another Chinese *Artemisia* specie, have total 37 components in its volatile oil which includes 14 alcohols, 17 terpenoids, 2 ketones, 2 esters and 2 other components but the main

constituents are  $\alpha$ -cadinol,  $\beta$ -bisabolol, cis-lanceol and epiglobulol (36).

### Toxicology

TARRALIN™ is an ethanol extract of *Artemisia dracunculus* (Russian tarragon), a commonly used medicinal and culinary herb that has been used from centuries. *Artemisia dracunculus* is a close relative of French or cooking tarragon, containing many commonly used herbs without reported side effects. Since the safety information for mugwort and its extracts is limited to historical use, TARRALIN™ was tested in a series of toxicological studies. Complete Ames analysis did not show any mutagenic activity with or without metabolic activation. TARRALIN™ was tested in an acute limit test of 5000 mg / kg and no signs of toxicity were found. In the repeated dose oral toxicity study of Rosanova et al. 2012 (108), the rats appeared to tolerate 1000 mg / kg / day. Subsequently, TARRALIN™ was tested in an oral subchronic 90-day toxicity study (rat) at doses of 10, 100 and 1000 mg / kg / day. No attention was paid to food intake or body weight, and functional signs of toxicity of the battery or exercise activity were observed. Gross autopsy and clinical chemistry did not show any effect on organ quality or blood chemistry, and no treatment-related lesions were found by microscopy. Therefore, TARRALIN™ appeared to be safe and non-toxic in these studies, and an unobserved level of adverse effects in rats was established at 1000 mg / kg / day. Toxicological study of the species *Artemisia Judaica* has been studied by Nofal et al. 2009 (109). They observed acute and chronic toxicity in the species.

### Status of *Artemisia* species in Pakistan

#### *Artemisia annua* L.

The common name of *Artemisia annua* in United States is annual wormwood, sweet wormwood or sweet annie while in Chinese it is called qinghao or huag hua hao (37). *Artemisia annua* is annual herb that is native to Asia but now naturalized throughout the world and is distributed in different countries like Pakistan, Iran, Afghanistan, South China, India, Central and South Europe, Australia, Malaysia, Thailand, Brazil, Burma, USA and Switzerland (38). This species starts flowering from August to September and is a fixed short day plant having critical photoperiod of 13.5 hours (37).

This has been considered in the sub-generic section of *Artemisia absinthium* or in both subsection *Abrotanum* and *Absinthium* (37). The morphology of the species revealed that this shrub is about 2m tall; single stemmed with alternating branches and alternating, aromatic and deeply dissected leaves ranges from 2.5-5cm in length. As for as the flowers are concerned, the tiny nodding flowers (Capitula) ranging from 2-3mm in diameter with bright yellow or greenish color. The florets at the center may be sterile or fertile, having inferior and unilocular ovaries and each produce only one achene, both central

and marginal flowers have tubular corolla as reported by Vallès, Garcia, Hidalgo, Martín, Pellicer, Sanz, Garnatje (39).

The Artemisinin is mostly produce in aerial parts of the plant, and mainly used as a source of essential oils in perfumes industries, vermouths and also to treat fever and hemorrhoids (37). Artemisinin (qinghaosu), an organic sesquiterpene lactone, is extracted from *A. annua* which is effected against *Trypanosoma* (40), leishmania, cancer (Sen et al., 2007) and also some viruses as reported by Sen, Bandyopadhyay, Dutta, Mandal, Ganguly, Saha, Chatterjee (41). The leaves and extracts of *A. annua* is the best source of antioxidants (42) due to the presence of large amount of flavonoid compounds that having anti-oxidants and anti-viral activity. Terpene peroxides such as *Artemisia* ketone, artemisinic alcohol, myrcene hydroperoxides and arteannuin B are extracted from this specie (43).

#### *Artemisia amygdalina* Decne.

The common name of *Artemisia amygdalina* is Almond Wormwood and also known as Veer Thethven in Kashmir, belongs to family Asteraceae and is endemic species to Pakistan (Khyber Pakhtunkhwa) and Kashmir Himalaya (44). It starts flowering from July to September, while the taxonomic characters revealed that this aromatic perennial herb is blackish-brown and up to 1.5m in height. Numerous stems are raised from the base which are erect, large and 0.5-1.5cm in diameter, grooved, glabrous however younger shoots are covered with hairs and leafy branches (45). In addition, leaves are simple, serrate, sub-sessile to sessile, glabrous, undivided, elliptic lanceolata, 9-15cm in length and 1-3.5cm in width, teeth curved inward, beneath hoary tomentose, hairless green above, gradually attenuate and eared at the base, climax long acuminate. Due to the structure of its leaves, it can easily distinguish from other species. The terminal portion of stems contains numerous flowering heads which are heterogamous, dangling, about 3-4mm across, peduncles are 1-1.5 mm long. Florets are up to 25, all of which are fertile while the outer florets are female in 8-10 with 2 toothed and having corolla of about 1mm long, style branches are flat while disc florets are hermaphrodite in which 12-15 with 5 toothed urceolate about 1.5mm long, glabrous, basally compressed corolla, anther appendages obtuse, protruding. Cypselas are 1mm long, cylindrical and glabrous (45).

Ethnobotanically, this species is mostly used for treatment of cold and cough and also have anthelmintic property so can be used as vermifuge (45).

#### *Artemisia dracunculus* Hook.

*Artemisia dracunculus* is a perennial herb, belongs to family Asteraceae (46) and commonly known as tarragon. This species have two varieties i.e. French tarragon (German tarragon) and Russian tarragon (47). The species is also widely cultivated across the world

mostly in Southern Europe, Russia, United States, Siberia, China and Mongolia (48).

Variable levels of polyploidy has been reported in *Artemisia dracunculata*, but like most of *Artemisia* species, it also possess base chromosome number  $x = 9$ , but it also have polyploidy  $2n=2x=18$  (49). The species is aromatic to odorless, and having a height of about 20-100 cm. it is erect, costate to seriate, and greenish-yellow in color. Stems may be hairy or hairless while leaves are short stalked or may be sessile, mostly undivided with lower 3-5 cleft, and are usually hairless, sometimes sparsely appressed canescent, that may be linear lanceolate or oblanceolate. Florets number is up to 40, yellow in color. The corolla is 5-toothed while the Cypselas are brownish in color, ellipsoid and length is 0.6-1 mm (45).

It also produces essential oils and wide varieties of secondary metabolites e.g. coumarins, phenyl propanoids and flavonoids etc. and some vitamins (50). It's essential oils have a lot of applications widely used in the treatment of many diseases. *Artemisiadracunculus* is related to worm wood and can stimulate uterus and digestive system and can helps in the lowering of fever and can destroy intestinal worms (51).

The essential oils of *Artemisi adracunculus* can be used as food flavorings, in detergents and also can be used as a medicine. The extracts and essential oils from different parts of *Artemisi adracunculus* can possess scavenging activities (52). It is mildly sedative and also possesses anti-convulsant activity because of the presence of mono-terpenoids in essential oils (52). It can also be used in the treatment of diabetes by controlling the pathogenesis of both diabetic patients and in pre-diabetic neuropathy (46).

#### ***Artemisia absinthium* L.**

*Artemisia absinthium* is a shrubby plant, and its stem is hairy and ribbed having a height of 1 meter. It is a perennial herb growing in northern areas of Pakistan. Commonly this species is known as "worm-wood" or vilayati afsanteen". It is found in Kashmir at a height of 2100 meter (53). The morphological characters of the species showed that this is oppressed and silky-canescens, erect, having a height of about 1.25 meter. Stem is terete and striate. Basal and lower stem leaves are long and having leaf stalk, petiole length is about 10 cm, lamina is extensively ovate, and its length is 8-15cm and width is 4-8 cm, 2-3-pinnatisect. The flowering season of *Artemisia absinthium* is June to September (45).The species produces essential oil and its constituents vary with the origin. The extract contains lignins, polyphenols and flavonoids (54). The essential oil of dried leaves contain  $\alpha$ -thujene, thujyl alcohol, p-cymene,  $\beta$ -phelandriene, caryophyllene oxide,  $\alpha$ -terpineol, geraniol, thujyl acetate, caryophyllene, 1,8-cineol, camphene methyl-heptenone,  $\alpha$ -pinene, elemol,  $\alpha$ -cadinene,  $\alpha$ -himachalene (55).

Several uses and applications of the species have been reported i.e. It can also be used for the treatment of several other disorders like urinary disorders, gastric problems, epilepsy, for wound healing, for enlargement of spleen disease and can be used as a digestive drug (56). In addition it possesses anti-microbial, anti-oxidant properties (57) and is hepato-protective (58).

#### ***Artemisia vulgaris* L.**

The species is commonly known as Mugwort, one of the several species of family Asteraceae that is cosmopolitan and mostly found in Europe, Northern Africa and Asia (59). The flowering period occur from august to November (45).

This aromatic perennial herb is rhizomatous, show greatest variation in morphology. The diameter of rhizomes ranges from few millimeters to 1cm and reach to the soil in depth of about 7-18cm.the stem is erect, simple, of about 0.4-1.5m in height, simple or branched, striated or deeply grooved, mostly green to brown in color at lower base while the upper stem is purplish and may be hairy. Leaves are in dark green color about 1-10cm in length and 3-7.5cm in breadth. Florets are 10-30 in numbers with yellow to reddish color (45).

The species have multiple uses i.e. it is used in the form of infusion, fluid extract, powder, distilled water. The infusion leaves of this species are used to treat fever (45).

#### ***Artemisia dubia* Wall.**

*Artemisia dubia* is a perennial herb, belongs to family Asteraceae and mostly found in hilly areas of Pakistan particularly in northern areas. It is an important source of Artemisinin, a widely accepted and most effective anti-malarial drug. Artemisinin can be produced by hairy root cultures of *Artemisia dubia*, and its production can be further enhanced by treatment of Gibberellic acid and salicylic acid (60). The morphological characters of *Artemisia dubia* exposed that it is erect; 1-1.8 meter in height, grooved, purpureu and glabrescent, strong woody stems with erect rootstock. Leaves may be petiolated or sessile and may be oblong-elliptic or may be ovate in shape. Florets are 16-20 in number, purplish in color, all are fertile. The flowering season of *Artemisiadubia* is from august to October (45).It possesses anti-malarial activity (61), anti-diabetic activity (13), anti-bacterial (62), anti-pyretic activity (63). It can also be used for the treatment of various types of carcinoma e.g. adenocarcinoma, lung squamous cell carcinoma, hepatocellular carcinoma and cervical carcinoma (64).

#### ***Artemisia scoparia* Waldst**

It is found mostly in lower region of Western Himalayas, Shimla hills, Eastern and Northern Punjab of Pakistan. The flowers and seeds of *Artemisia scoparia* are aromatic parts of the plant and contain essential oils and lactone, having a lot of medicinal properties.

Taxonomically, it is biennial or perennial herb, which is woody, and branches may be several or solitary in upper

**Table 1** Different species of genus *Artemisia* in Pakistan with their medicinal values and Phytochemicals.

S. No	Species found in Pakistan	Medicinal Properties	Phytochemicals	References
1	<i>Artemisia japonica</i>	Possess anti dermatological and antimalarial properties.	Presence of essential oils, such as Linalool, Germacrene D, ( <i>E</i> )- $\beta$ ocimene, 1, 8-Cineole, ( <i>Z</i> )- $\beta$ -ocimene and high concentration of artemisinin in aerial part of plant.	(81) (82) (83) (84)
2	<i>Artemisia dracunculus</i>	Antimalarial	Artemisinin	(84)
3	<i>Artemisia amygdalina</i>	The plant parts are used to cure epilepsy, nervous disorders, cough etc	Presence of terpenes, alkaloids, phenolics, tannins, polyphenolics, cardiac glycosides and steroids	(85) (86)
4	<i>Artemisia scoparia</i>	Hepatoprotective against Acteaminophen, Antidote- antivenin properties. This plant has laxative properties. Nephro-protective characteristics to cure kidney disorders Aerial parts are applied in sore throats and epilepsy.	Presence of Artemisinin, sterols, flavonoids, Kaempferol, rutin, apigenin, caffeic acid.	(87) (82) (88) (89) (90) (91-93)
5	<i>Artemisia sieversiana</i>	This plant has wide array of medicinal properties to cure dyspepsia, and blood pressure. Furthermore, it has an anthelmintic property.	High concentration of Artemisinin was found in root parts.	(94) (84)
6	<i>Artemisia absinthium</i>	Antimalarial activity	Presence of antimalarial compound known as Artemisinin	(95) (96)
7	<i>Artemisia rutifolia</i>	Root of plants are used to treat tooth ache and stomach disorders	Presence of high concentration of polyphenol compounds including gallic acid, caffeic acid, chlorogenic acid, syringic acid, sinapic acid, <i>p</i> -coumaric acid, <i>m</i> -coumaric acid, ferulic acid, vanillic acid, myricetin, and quercetin.	(97) (98)
8	<i>Artemisia dubia</i>	Leaf powder and fresh leaves to treat stomach disorders and skin infections.	Higher concentration of Artemisinin in floral part of <i>Artemisia dubia</i>	(99) (84)
9	<i>Artemisia macrocephala</i>	Potential antioxidant, anticancer and antispasmodic activities	Presence of sesquiterpenes lactones and flavonoids	(100, 101)
10	<i>Artemisia elegantissima</i>	Due to presence of wide array of compounds, this plant has strong potency to develop antitrypanosomal drugs	13 compounds such as, ( <i>Z</i> )- <i>p</i> -hydroxy cinnamic acid, stigmasterol, $\beta$ -sitosterol, betulinic acid, bis-dracunculin, dracunculin, scopoletin, apigenin, dihydroluteolin, scoparol, nepetin, bonanzin, and 30,40-dihydroxy bonanzin were reported.	(102)

11	<i>Artemisia vulgaris</i>	Antispasmodic and antidiarrheal activities	Crude extracts of plants tested positive for the presence of alkaloids, coumarins, flavonoids, saponins, sterols, tannins and terpenes	(103)
12	<i>Artemisia incisa</i>	Antifungal activity	New compound was extracted while using spectroscopic techniques. New compound was identified as Santolinyol-3-acetate (4-(2-hydroxypropan-2-yl)-2-methylhexa-1,5-dien-3-yl acetate) was extracted.	(104)
13	<i>Artemisia moorcroftiana</i>	Plant extract is used to treat malaria fever	Presence of Artemisinin in A. moorcroftiana.	(81) (84)
14	<i>Artemisia roxburghiana</i>	Plant parts are used to cure diabetes	Presences of Protein tyrosine phosphatase 1B inhibitors in plant extracts validate the ethno botanical usage to cure diabetes.	(81) (105)
15	<i>Artemisia annua</i>	Leaves are used to treat fever and malaria	Presence of total phenolic (TPC), flavonoid (TFC) contents were detected in foliar parts of plants. This plant has antioxidant potential	(82) (106)
16	<i>Artemisia persica</i>	Antioxidant capacity	Traces of flavonoids and phenolic were observed in dried extract	(107)

part, height is 40-80 cm, patulous may be hairy or hairless, stems are tint from upright branched rootstock in purplish-brown color. Florets are 10-12 in number, yellowish in color. The marginal florets are 5-6 in number and all are fertile, which is 0.7 mm long, tubular in shape, 2-dentate corolla is 2-dentate. The flowering season of *Artemisia scoparia* is from July to November reported by (45).

*Artemisia scoparia* has a lot of uses and applications. It possesses medicinal properties and can be used for the treatment of fever, bronchitis, cough, and jaundice, earache, diuretic and purgative. The extract of *A. scoparia* can be very effective in treating of cardiac problems and against poisonous insect bite (65). The dried part of the *A. scoparia* can also be used as an ornamental plant, as a vegetable for human food and as a medicine, also used for treating burns and also possesses hepato-protective activity (66). It can also be used as an immune-suppressant agent, with vaso-relaxant action and effective for the treatment of auto-immune diseases and to prevent transplantation rejection because it contains chemical "scoparone" (67).

#### ***Artemisia roxburghiana* Wall.**

*Artemisia roxburghiana* is also important specie, belonging to genus *Artemisia* and family Asteraceae. It is a perennial herb and mostly found in Himalayas at altitude of 10,000 to 43,000 meters (68). It is widely

distributed in many parts of the world and is cultivated in China, India, Nepal, Pakistan and Afghanistan (45).

*Artemisia roxburghiana* is a perennial herb, with several or single, upright or erect, 20 – 50 cm long, grooved, and possesses hairs of white color, stems are often tinged in purplish color from horizontally creeping, 1 cm thick rootstock. Leaves are short winged petiolated to sessile, oblong-ovate to elliptic rotund in shape, 5–18 cm long and 3–10 cm wide, and its axis is without lobules, possess hairs very scantily and which are greenish in color from above, and greyish-white in color from beneath. Florets are 20 – 38 in number, usually purple-brown in color, and all are fertile. The flowering season of *Artemisia aroxburghiana* is August to October (45). The species is very novel and effectively used for the treatment of skin allergies, and used as an anti-pyretic tonic (69). It is also used to treat eczema, sores and pimples (70).

#### **Conclusions**

From the present study it is concluded that *Artemisia* is very diverse, and 25 species of the genus has been reported from different climatic zones and areas of Pakistan. The genus produced artemisinin which is potential source for the treatment of different ailments. *Artemisia* yields oils and its constituents vary with the origin. The extract contains lignins, polyphenols and flavonoids. The constituents of essential oil of this species



are  $\alpha$  and  $\beta$  thujone, epoxyocimene and chrysanthenyl acetate, sabinyl acetate. These types of investigations on Pakistani species are yet not known, which needs to be explored. The genus has strong aroma which has strong allelopathic effect on different cereal crops and other plants which needs special attention by the researchers. The explorations of such information will be helpful to find out the possible solutions for increasing the yield of cereal crops in the region. The genus is famous for their ethnobotanical uses therefore, the local communities exploiting the species at alarming rate. This practice will lead to the rapid degradation of this medicinally important genus. Based on present evidence it is suggested that the genus *Artemisia* need conservation and proper management.

### Conflict of interest

The authors declared no conflict of interest.

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