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REVIEW ARTICLE

A comprehensive review on occurrence, phenology, traditional uses, chemical composition and pharmacological properties of *Abelmoschus moschatus* Medik

Ratanajay Sharma[1], Vartika[1], Satish Kumar[1], Vaibhav Sharan Pandey[1,2], Ajay Dhawal[1], Rakesh Pandey[1] and Vashist N. Pandey[1*]

Abstract

Abelmoschus moschatus Medik occurs worldwide including India. North Eastern Terai Region of UP., India situated at foothills of himalayas harbours many lush green vegetation with A. moschatus. Traditionally roots, stems, leaves, fruits and seeds of musk mallow used in medicine. The capsules and leaves are used as vegetables. The present paper deals with the occurrence, phenology, traditional uses, general healthcare, phytochemicals and pharmacological properties of A. *moschatus* in India. In addition, the holistic approach of the plant in general health care benefits, nutraceuticals and industrial uses were also discussed.

Keywords: Abelmoschus moschatus, Phenology, Traditional uses, Phytochemicals, Nutraceuticals, Pharmacology.

Introduction

Abelmoschus moschatus is an erect, annual, hispid, herbaceous shrub (Fig. 1) commonly known as Kasturi bhindi, Musk mallow, Ambrette, Kasturi Lata, and Dullah in Bhojpuri, which belongs to family Malvaceae **(**Sebastian *et al*. 2022; Pathak *et al*. 2023).

The plant is native of India and found in many parts of world viz. China, Asia and Islands of Pacific Ocean (Fig. 2). Seeds of the plant contain essential oil which is musky in nature. Plants are cultivated for perfume production from its seeds (Devi *et al.* 2023).

The roots, leaves and seeds are used as herbal remedy, while the capsules and leaves are also used in meals. The plant has great importance in pharmaceutical and food industries (Pawar and Vyawahare 2017). Traditionally musk for fragrance has been obtained from the pod of male musk deer but only after the sacrifice or death of the deer. This makes it costly, unique and unethical. The musk odorant material is obtained from seeds of *A. moschatus* which is abundant, cheap and easily available. The seed of the plant is a potent source of musk odorant substance. These seeds are a better economical and an ethical substitute for animal musk (Dwivedi *et al*. 2013; Navgire and George 2016; Patel *et al*. 2021). The review discuss about the occurrence, phenology and folkloric uses with botanical, economical, phytochemical and some pharmacological description.

Study Area

The North-Eastern Terai Region of U.P. (NETRUP), India is situated at foothill of Himalayas between river Rapti and Gandak, tributaries of Ganga. The landform contains good natural vegetation, occupancy and composite farming that has been largely operated by mankind. The NETRUP includes 11 districts viz., Kushinagar, Deoria, Gorakhpur, Maharajganj, Sant Kabirnagar, Basti, Gonda, Siddharthnagar, Shravasti, Balrampur and Baharaich of Uttar Pradesh (Pandey and Srivatava 1991; Shukla 2009; Dhawal *et al*. 2023). It lies

[1]Experimental Botany and Nutraceutical laboratory, Department of Botany, DDU Gorakhpur University, Gorakhpur- 273009 U.P., India.

[2]Department of Botany St. Andrew's College, Gorakhpur- 273001 U.P., India.

***Corresponding Author:** Vashist Narayan Pandey, Experimental Botany and Nutraceutical laboratory, Department of Botany, DDU Gorakhpur University, Gorakhpur U.P. - 273009, E-Mail: vnpgu@yahoo.co.in

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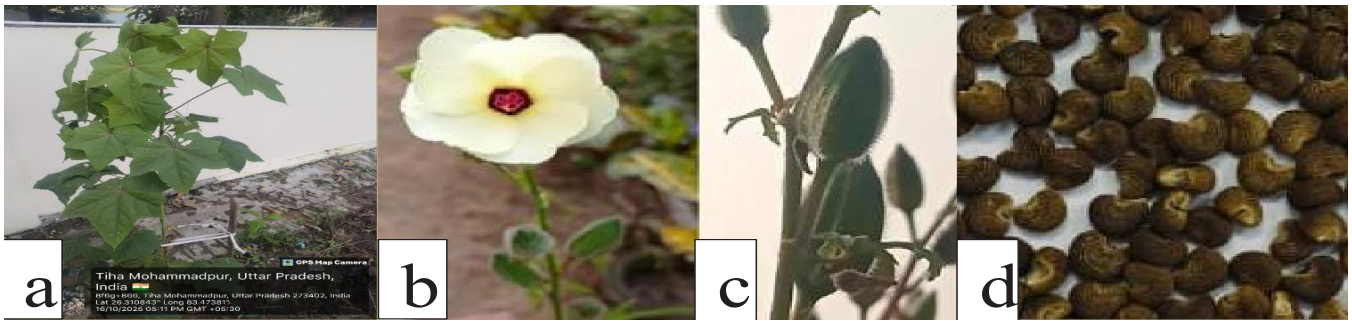


Figure 1: (a) Whole plant of *A. moschatus* (b) Twig with ca psule (c) Fruit (d) Seeds

between 26° 6′ to 27 ° 4′ N latitude and 81°6′ to 84° 26′ E longitude.

Habitat

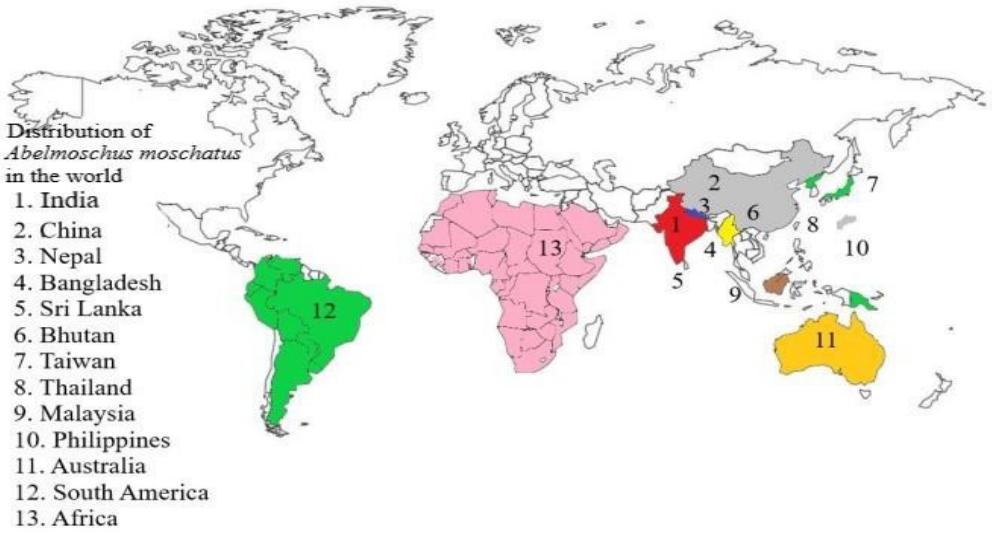
Plants are naturally growing as wild. However, it is grown in moist rich, well-drained loamy to sandy loamy soils in the area under study. The suitable pH ranges in between 5.5 – 7.0 (tolerable pH 5.0 – 8.0), temperatures range 20 - 30°C (tolerable temperatures 0 - 5°) and adapted to the annual rainfall varies from 100-140 cm (Orwa *et al*. 2009). Plants are growing in April-May as pre-kharif crop in India but as late as the first week of July in central India. Flowering occurs from August and harvesting starts from August to November when most of the capsules are showing slits and open when the colour of pods changes to brown. Capsules collections are very tough because they contain hairy spines on their surface that causes itching. Plants are growing as an irrigated and rain fed crop. It is growing in both well drained loamy and sandy soils. Soil with neutral pH and huge organic material are favorable for its farming (Grenand *et al*. 2012; Mishra *et al*. 2020).

Distribution

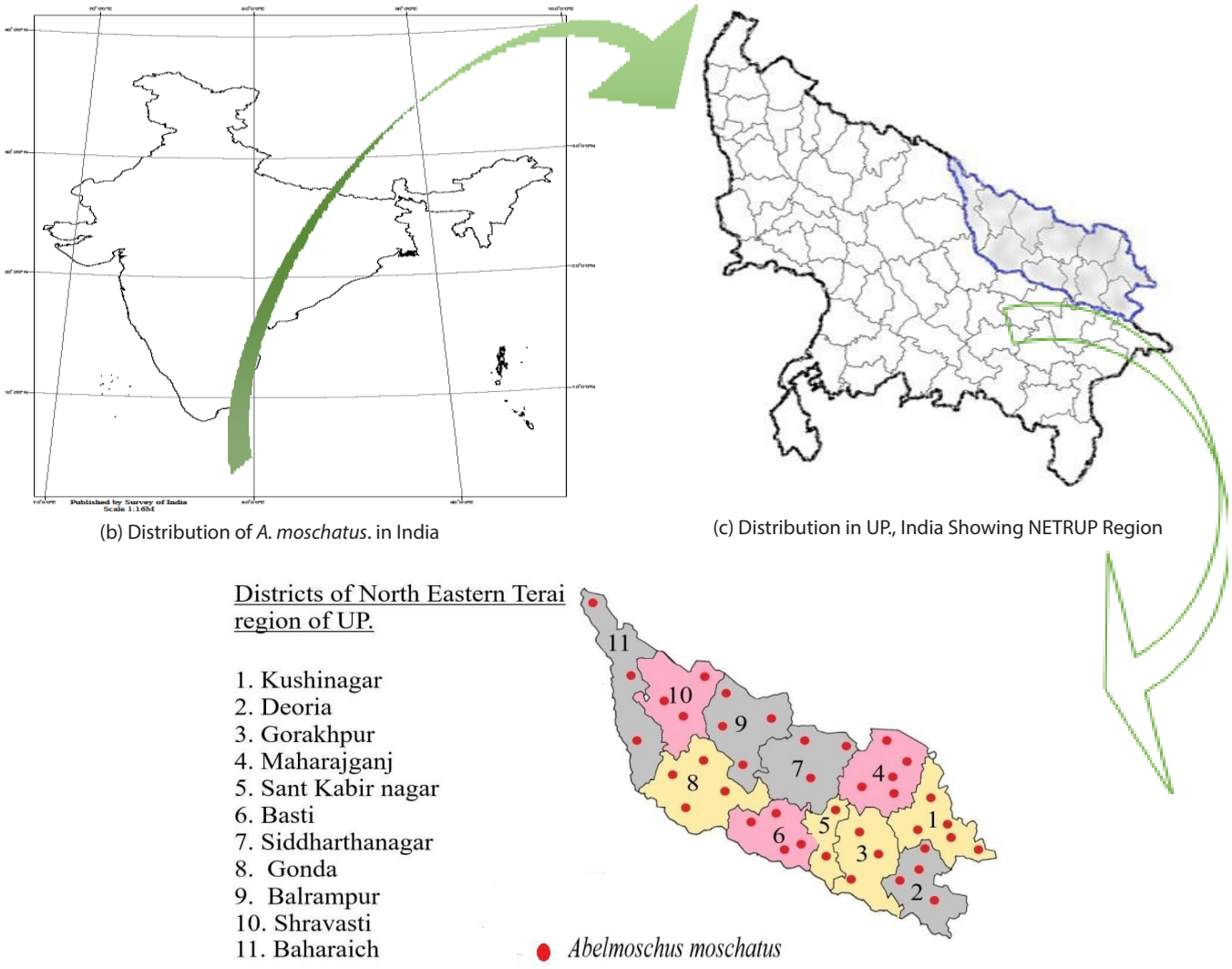
A. moschatus is distributed worldwide in both the hemisphere of tropical and subtropical regions including India, Southern China, Nepal, Vietnam and South East Asia. In India it is generally distributed and cultivated in hilly region of Karnataka, Deccan and NETRUP in foothills of the gangetic plains of Himalayas. However, it is widely found in nature where water lodging is absent. The plants prefer slightly slopy area for their cultivation (Giri *et al*. 2016; Rani *et al*. 2022). The plant is distributed in different sites of study area especially in NETRUP, India (Fig.2).

Description

A. moschatus is an erect annual, hispid herbaceous plant and its length varies between 1.5 to 1.9 m which have rammer like tap root. It bear coarse hairy palmately compound leaves which have 4 to 5 lobes and its length was 11-15 cm long. The seeds are situated inside rigid, papery and hairy capsules which are up to 6 to 8 cm long, Inflorescence axillary, solitary, flowers bisexual, pedicel slender, epicalyx 6-10 free, calyx 5 lobed, petals 5 large, obovate, apex rounded, glabrous and



(a) Worldwide Distribution of *Abelmoschus moschatus*



(b) Distribution of *A. moschatus*. in India

(c) Distribution in UP., India Showing NETRUP Region

d) North Eastern Terai Region (NETR) showing distribution of A. moschatus.

Figure 2: Distribution of *A. moschatus* in the world, India and NETRUP.

yellow or pink in color. Its flowers look like *Hibiscus* which is usually light pink color and sometime white or light yellow in color. Stamen's indefinite, monadelphous, epipetalous, filament short, introrse, anthers basifixed, Ovary superior, 5 locular, ovules many with axile placentation. Fruit (capsule) densely hispid, dehiscent through longitudinal slits towards the base and includes many reniform seeds (Sharma *et al*. 2020; Rani *et al*. 2022).

Phenology

Life form

The life form germinates through seeds during rainy season in June to first week of July in India.

Lifecycle

Plant is easily grown in moist rich, well-drained loamy to sandy loamy soils in a slightly acidic medium through seeds which prefers pH 5.5- 8.0. It follows the pre-kharif crop cycle in north India but as late in the first week of July in central India. Flowering occur from September and harvesting starts from November to January when most of the capsules are showing slits and opening and the colour of pods being changed from green to brown. Harvesting of pods is very tough because they contain hairy tiny spines like structure on their surface that causes itching (Datta *et al*. 2011; Grenand *et al*. 2012).

Variability

The plants are variable according to their plantation in irrigated as well as in rain fed area. The suitability of the plant growth occurs, temperatures ranges between 20-30°c with an average annual rainfall 100-140 cm. Variability in flowering and fruiting season is also recorded in different region of the country due to slight change of climate (Orwa *et al*. 2009).

Germination

Germination is through seeds. Germination of the plant is easy and convenient. It can be done by two methods one is dry and other is wet. In dry method the dried seeds are shown in well irrigated soil whereas in wet method the seeds of plant are placed in water overnight for activation of enzyme and to break dormancy, so that plant can germinate easily (Geetharani *et al*. 2008). Life cycle of *A. moschatus* is given in Fig 3.

Traditional uses

Folkloric use

The young leaves, shoots and pods of Ambrette have musky fragrance which is used in the preparation of soups, perfumes, soaps, detergents, creams and lotions. The leaves and stems are also used to clarify jaggery (Patel *et al*. 2020). Immature fruits are traditionally eaten in many areas of the globe. Seed of the plants are used as flavoring agents for liquors and coffee. Mucilaginous substance present in flowers is used as flavoring agent. Scented oils extracted from the seeds are used in making sweets, icecream and light drinks (Prajapati *et al*. 2003; Dwivedi 2009). The traditional utilization of Musk mallow is given in Table 1.

Phytochemical Analysis

Phytochemicals of the Ambrette are potential source of metabolic activities of human beings and animals. These

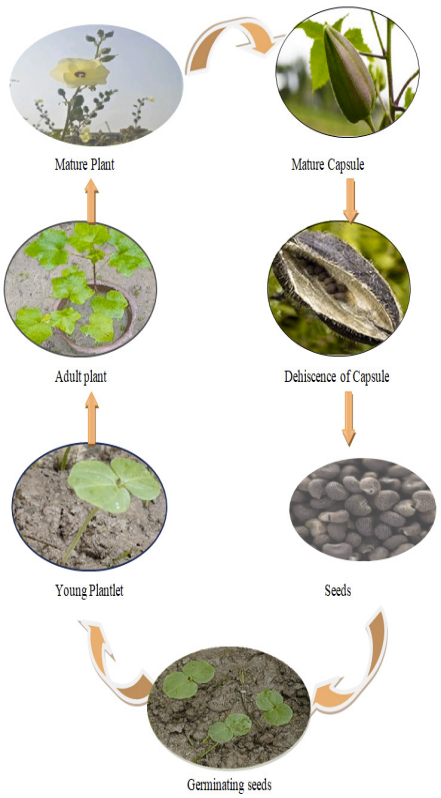


Figure 3: *A. moschatus* showing different stages of life cycle.

chemicals are carbohydrates, protein, lipids, vitamins and minerals. The primary metabolites in later stages produced many secondary bioactives glycosides, alkaloids, fatty acids flavonoids, phenols, gums, polysaccharides, terpenoids and tannins (Harborne 1973; Dubey *et al.* 2013; Pandey *et al.* 2019; Mohite and Gurav 2020). The schematic flow of metabolites from *A. moschatus* are given in Fig 5. How these molecules act on the different organs of the body for the health benefits in general as well as specific for brain, heart, liver, kidney, lungs and gastrointestinal tract etc. The plant part extracts were analyzed for carbohydrates, proteins, alkaloids, flavonoids, sterols, anthocyanin, phenolic compounds, tannins, fats and fixed oils. Biochemical analysis of seed showed moisture (11.1%), mucilage (6%), crude fiber (31.5%), fatty oils (14.5%), starch (13.4%), protein (2.3%), resins (5.0%) and volatile oil (0.2 to 0.6%) (Orwa *et al*. 2009; Garg and Jain 2019). Seed oil contains (Z)-7-hexadecen-16-olide, (2Z, 6E)-farnesyl acetate, (Z)-9-octadecen18-olide, (2E, 6E)-farnesyl acetate, β-farnesene, decyl acetate, (Z)-5-tetradecen-14- olide, nerolidol, dodecyl acetate and (Z)-5-tetradecenyl acetate. The fragrance of oil is primarily due to the company of ambrettolide (Z)-7-hexadecen16-olide) a ketone which is a lactone of ambrettolic acid (Garg and Jain 2019; Joseph *et al*. 2020; Pise and Thorat 2023). The fatty oil of seed contains the phosphatidylserine, phospholipids-2-cephalin, plasmalogen and phosphatidyl choline. Leaves contain ambrettolic acid lactone, β- sitosterol, β-d –glucosides and farnesol. Corolla possessed flavonoid, β-sitosterol, myricetin and glucoside in their petals. Flowers possessed cyanidin-3- glucoside and Cyanidin-3-sambubioside bioactive compounds (Dwivedi and Argal 2016; Patel *et al.* 2019; Devi *et al.* 2023). Bioactives and their activities were recorded in Table 2.

Carbohydrates

Carbohydrates are present in form of mucilage which contains neutral sugars, minerals and polysaccharides showing anticancer, antimicrobial, antiulcer and hypoglycemic activities. Mucilage is found in plants and some microorganisms. Musk mallow mucilage is used in formation of colon specific metronidazole (MNZ). It was analysed for rheological and physical characters. These mucilaginous non- cytotoxic polysaccharides were used to characterize various rheological characters under variable situations. Various formulations were used for amoebiasis. Metronidazole is absorbed in gastrointestinal tract which performed therapeutic action at 500mg single dose after 1 hrs of taking (Liu *et al*. 2010; Sharma *et al*. 2020).

Now a days, the researchers have greatly emphasized on mucilage-based products as excipient, tablet binder, thickeners, purifiers, colloids, gum substitute, gelling agents and in rheological management (Tomoda *et al.* 1987; Singh *et al*. 2017; Pandey *et al*. 2019; Devi *et al.* 2023). The plant of Ambrette showed mucilage was made of rhamnose

Table 1: Traditional Utilization of *A. moschatus* in Folklore Medicine

S. No.	*Part Used*	*Uses*	*Mode of preparation*	*References*
1.	Root	Used in Paper and Liquorindustries	Mucilage obtained fromfresh root.	(Lalmuanthanga *et al*. 2019)
2.	Stem	Used in making ropes,linen, fishing nets bags	Fibers obtained frombark of the stem	(Duke 2002)
3.	Leaves	Antivenom, Vegetables,Perfumes and Soups	Fresh Juice obtained by crushing leaves and given orally	(Jain *et al*. 2011; Mitra and Mukherjee 2014; Shukla *et al*. 2022)
4.	Leaves	Soups, perfumes, soaps, detergents, creams andlotions	Semi solid lotions highly crushed to very fine paste	**(**Dwivedi 2009; Rani *et al*. 2022)
5.	Leaves+ Stem+ Root	To clarify jaggery in gur industry	Fresh Plant as such added to boiling cane sugar juice	(Dwivedi 2009)
6.	Leaves	Food and Fodder	Fresh leaves and pods are eaten by animal	(Dwivedi 2009; Dutta *et al*. 2011)
7.	Flowers	Used as Contraceptive	Flowers infusion is obtained by crushing	(Jain 1991; Sebastian *et al*. 2022)
8.	Unripe Fruits	Used as Vegetables and Tea	It is orally used as vegetables, juice and topically as semi solid paste in skin care	(Dutta *et al*. 2011; Jain 2011)
9.	Seed	Preservation of cloths from Paste	Dried seeds are placed between cloths	(Sebastian *et al*. 2022)
10.	Seed	Used in aphrodisiac, allay thirst, hysteria, stomatitis, dyspepsia, urinary discharge, leucoderma, gonorrhoea, Itching, antispasmodic, emollients and demulcents	Plant extract Used as tonics	(Jain 1991; Rani *et al*. 2022; Dokka *et al*. 2022)
11.	Seed	Used as flavouring agents in liquors and coffee	Dried seed powder	(Lalmuanthanga *et al*. 2019; Joseph *et al*. 2020; Rani *et al*. 2022)

and galacturonic acid. Powder of mucilage was used in making upma, idli, roti etc to evaluate its nutritive value and acceptability. Mucilage products were evaluated for colour, texture, taste and flavour (Pandey and Dubey 2014; Nazni and Vigneshwar 2014).

Flavonoids

Flavonoids and polyphenols were evaluated for accumulative and antioxidant activities. Food and medicine value were evaluated for sensitivity of insulin to manage glucose level in blood (Liu *et al*. 2010; Pandey *et al*. 2019)**.**

Anthocyanins

Anthocyanins are a group of naturally occurring pigment of flavonoid derivative molecules present in the flowers of ambrette plants and their colour varies with ph. Flowers contain cyanidin-3 glucoside and cyanidin-3-sambubioside. The leaves contain β -D glucoside, β–sitosterol, myricetin and glucoside **(**Khare 2004; Garg and Jain 2019).

Volatile compounds

The seeds of *A. moschatus* contain 93 biomolecules. The volatile compounds of the seed coats were mainly 2-methylbutyl-2-methylbutanoate. The other compounds were decanal (1.6-5.7%); isopentyl 2- methyl butanoate (0.2-14.3%), n-tridecane (1.5-26.9%) and heptanoic acid 2-methylbutyl ester (6.6-13.5%) are also reported (Pandey and Srivatava 1991; Nautiyal *et al*. 2011; Garg and Jain 2019; Kumar *et al*. 2020; Kumar *et al*. 2021; Kumar *et al*. 2023).

Bioactive constituents

A comprehensive evaluation of basidic Co_2 extracts of seeds showed that 58 volatile components which have 27 pyrazine derivatives, 7 thiazoles and 12 pyridines including natural bioactive compounds given in Fig 4.

Musky fragrance of seeds essential oil is due to (Z)-hexadec-7-en-l6-olide and (Z)-tetradec-5-en-l4-olide (Rout *et al*. 2004; Du *et al*. 2008; Nazni and Vigneshwar 2014; Patel *et al*. 2019).

Pharmacological properties

The plants parts have been used traditionally for the treatment of many diseases. Every part of this plant is used in Ayurvedic medicine and Traditional Indian Folk Medicines (Dwivedi 2009). Seeds are potential source of essential oil which is used in cosmetics and perfumeries. It is added in the baked products, alcoholics, chewing tobacco and sweets. The leaves and flowers of the plant are helpful in curing of dermatitis and applied as balm on swelling. Many seeds were put between the cloths to protect damage from pests. Seeds were used in making incense sticks, which is repellent tablets and hair oil perfume (Khare 2004; Datta *et al*. 2011; Dwivedi *et al*. 2013; Patel *et al*. 2021).

Table 2: Some important bioactive compounds of ***A. moschatus***

S. No.	*Extracted from plant parts*	*Bioactive Compounds*	*Pharmacological Uses*	*References*
1.	Roots	Heptanoic acid 2- methylbutyl ester, n-tridecane, isopentyl 2- methyl butanoate and decanal.	It cures gonorrhoea and venereal disease.	(Nautiyal and Tiwari 2011)
2.	Leaves	Farnesol, Ambrettolic acid, Beta –sitosterol and beta- d-glucoside.	Perfume, Soap, ice- cream and soft drinks.	(Jain *et al*. 2011; Dwivedi *et al*. 2009)
3.	Flower	Cyanidin-3 glucoside and Cyanidin-3-sambubioside.	It is used as contraceptive	(Jain 1991)
4.	Fruits	Polysaccharide (Galactuonic acid and rhamnose).	Intestinal disorder, constipation, dyspepsia, cramp, stomach cancer and Vegetables.	(Sharma *et al*. 2020)
5.	Seeds	Farnesol, phospholipids 2- cephalin, Phosphatidylserine, Phosphatidyl choline plasmalogen, Lactone of ambrettolic acid etc.	Aphrodisiac, allay thirst, urinary discharge, leucoderma, perfume, liquor and coffee.	(Devi *et al*. 2023)
6.	Seed coat	2-Methylbutyl-2- methylbutanoate.	Perfumes, soap, detergent, Cream and lotion.	(Nautiyal and Tiwari 2011)
7	Whole plant	Polysachharides, volatile oil, fixed oil, tannins, protein, sterols, flavonoids, fatty acids and phenolic compounds.	Tablet binder, gelling agents, purifiers, colloids and to prepare idli- upma.	(Nazni and Vigneshwar 2014)

Antivenom and Antidote Activity

Plant part viz. leaves, fruits and seeds are useful to control snake bite especially in cled cobra and king cobra (*Naja naja*). Leaves and fruits juice either independently/ separately or both are given orally, a deep cut at the site and let blood flow freely and a parts of these are applied to the bitten area. It is used as antidote by Bhil, Meena and Sahariya of Rajasthan with milk (Table 1). Periodic application is carried on after 2hrs gap for 24 hrs not less than prior to snake- bitten individuals is think at out danger (Jain *et al*. 2011; Mitra and Mukherjee 2014; Shukla *et al*. 2022).

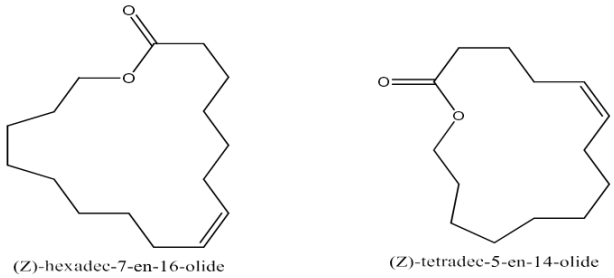
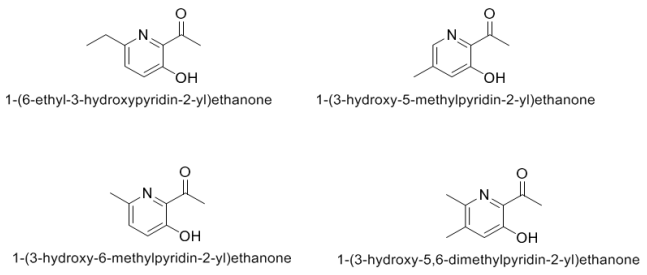


Figure 4: Volatile compounds

Antimicrobial properties

Extracts of leaves of *A. moschatus* in aqueous, hexane, methanol and ethyl acetate were analyzed for antimicrobial activities against pathogen. Antimicrobial activities were shown against *Bacillus megaterium, Corynebacterium diphtheriae*, *Proteus mirabilis, Proteus vulgaris, Shigella flexneri* and *Staphylococcus aureus*. Aqueous seed extract showed activities against *Escherichia coli, Bacillus subtilis, Pseudomonas vulgaris, P. aeruginosa, Salmonella enterica paratyphi* and *Staphylococcus aureus*. The hexane fraction showed strong antibacterial activities against *Corynebacterium diphtheriae* due to essential oil. Hydroalcoholic extract of leaves showed antimicrobial activities against *Candida albicans* (Pawar and Vyawahare 2017; Bose *et al*. 2024).



Antibacterial and antifungal activities were obtained from seeds due to a novel trypsin inhibitor (AMTI-II). AMTI-II exhibited potent bactericidal against *Bacillus subtilis, Bacillus cereus, Escherichia coli, Staphylococcus aureus, Proteus vulgaris, Streptococcus pneumoniae* and it was mild active against *Klebsiella pneumoniae, Pseudomonas aeruginosa, P. syringae* and *Streptococcus pyogenes*. AMTI-II also affects the growth of fungal species *Aspergillus flavus, A. niger, Candida albicans, C. glabrata, C. tropicalis* and *Saccharomyces cerevisiae* (Dokka and Davuluri 2014). Antibacterial activities of musk seed oil against Gram+ve and Gram-ve bacteria showed protective effect against Staphylococcus aureus, Bacillus subtilis and Enterococcus faecalis whereas less effective against *Pseudomonas aeruginosa*. Antibacterial activities of Musk seed oil and streptomycin were tested against bacterial strains. Maximum zone of inhibition were

observed in *Staphylococcus aureus* and *Enterococcus faecalis* (13.0 ± 0.5; 13.0 ± 0.8) followed by *Bacillus subtilis (*12.0 ± 0.5) and *Pseudomonas aeruginosa* (09.0 ± 0.7). However, streptomycin (30µg/ml) showed maximum inhibition in *Bacillus subtilis (*28.0 ± 1.2) followed by *Staphylococcus aureus* (20.0 ± 1.4), *Enterococcus faecalis* (15.0 ± 1.6) and *Pseudomonas aeruginosa (*15.0 ± 1.5). Ambrettolide and farnesol acetate present in oil are responsible for the antibacterial action. These constituents act on bacterial cell membrane due to its hydrophobic properties. Strains of Gram +ve bacteria were more susceptible than Gram –ve bacteria due to their membrane structure (Pawar and Vyawahare 2017; Dokka *et al.* 2022; Pise and Thorat. 2023).

Larvicidal Activity

Ambrette root extracts was tested against the larvae of *Anopheles* and *Culex* for larvicidal activity. The hydrated root extracts were effective tested against the larvae of *Anopheles culicifacies, An. stephensi* and *Culex quin-quefasciatus* showed lethal at concentration (LC50) were 52.3, 52.6 and 43.8 ppm respectively (Pawar and Vyawahare 2017).

General Healthcare

Infusions of leaves, seeds and pod calyces of the plant, generally used as a medicated tea in India, Nepal, Africa and U.S.A. Essential Oil from Ambrette seeds have fragrance smell. It is used for gastrointestinal disorders like vomiting, nausea, constipation, loss of appetite and stomach cramps. The formulations were used orally for remedy of arthritis, urinary incontinence, anxiety, muscle spasm, headaches, snake bites, sexual problems, fluid retention, gonorrhea, lung problems and heart failure. It is also an ingredient in fortified wine, bitter and more products (Prajapati *et al.* 2003; Dwivedi *et al.* 2013). According to Unani system of medicine seeds are used in curing of aphrodisiac, dyspepsia, urinary discharge, stomatitis, leucoderma, antispasmodic, itching, fulfill thirstiness and also used as restorative. It arrests vomiting treating nervous and intestinal disorders, skin diseases, hysteria etc. The shiny seeds are moisturizer

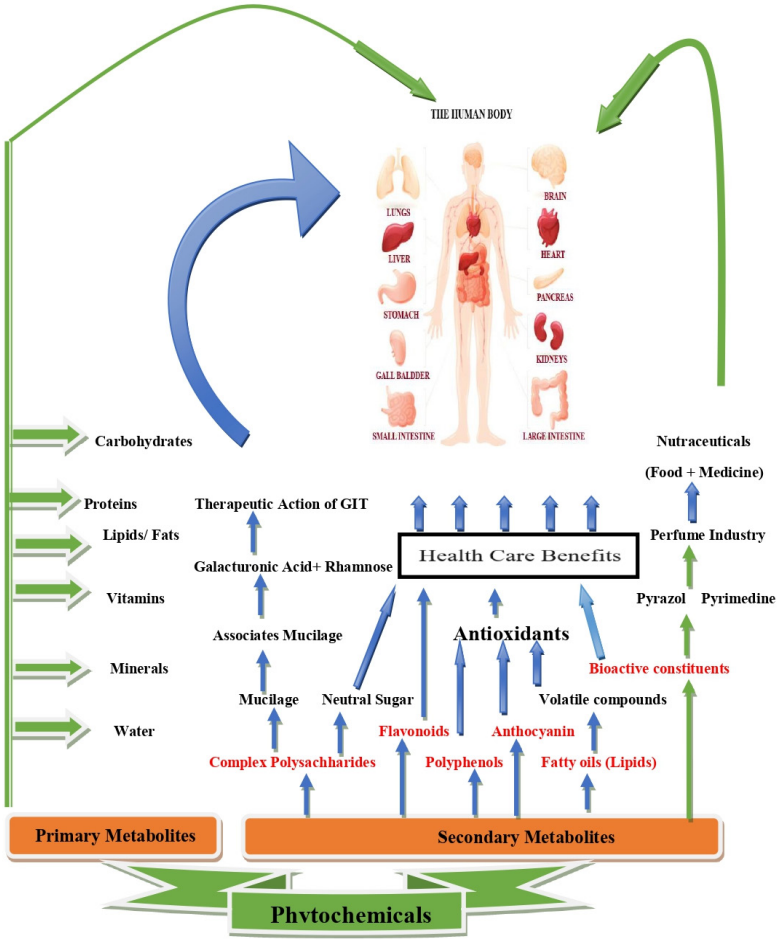


Figure 5: Phytochemicals of Abelmoschus moschatus in holistic Health care.

and palliative. Roots and leaves are cures for gonorrhoea. Flowers's suffuse used in birth control. Plant parts have many uses, used in complementary and conventional therapy (Jain 1991; Gul *et al*. 2011; Singh *et al*. 2017; Patel *et al*. 2019; Pandey *et al*. 2019; Mishra *et al*. 2020; Dokka *et al*. 2022; Pal *et al*. 2022). The general health care benefits were given in Fig 5.

Conclusion

A. moschatus is a significant nutraceutical plant with a long history of use. It holds a unique position in its native region. Its occurrence, phenology, and distribution patterns provide insights into its utilization. It produces many health benefits for stomach, small intestine, large intestine, lungs, liver, gall bladder, kidneys, pancreas, and brain because of biofunctional phytochemicals, in addition to primary metabolites. Pharmaceutical and clinical studies will be a new hope for drug discovery and drug formulation. The life cycle underscores its importance in daily human life as a source of food, medicine, and nutraceuticals.

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Query

Q1 Kindly provide a proper and clear picture for Figure 2 with the desired modifications as it cannot be edited from our end