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ORIGINAL RESEARCH ARTICLE

Comprehensive Analysis of Macroscopic and Microscopic Features of *Solanum Xanthocarpum* Schrad. & J.C. Wendl. (*Kantakari*): Root, Leaf, Flower, Stem, and Fruit

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ABSTRACT

Introduction: *Solanum xanthocarpum* Schrad. & J.C. Wendl. (commonly known as Kantakari) is a significant plant in traditional medicine, known for its distinctive therapeutic properties. This study aims to provide a comprehensive analysis of the macroscopic and microscopic features of *S. xanthocarpum*, with a focus on its root, leaf, flower, stem, and fruit.

Methods: In macroscopic examination, the physical attributes of fresh sample of *S. xanthocarpum* were documented, including size, shape, color, and texture of various parts (root, leaf, flower, stem, and fruit). For microscopic analysis, advanced microscopic techniques were employed to analyze the cellular structure and arrangement of *S. xanthocarpum* Schrad. & J.C. Wendl. Literary reviews from various Ayurvedic texts were also being considered to know the property of *Kantakari*.

Result: Key identifying features such as vascular bundles, trichomes, and stomatal patterns were highlighted. Samples were prepared using standard histological procedures and observed under a light microscope. *S. xanthocarpum* Schrad. & J.C. Wendl. root is cylindrical, branched, tapering, 5–8 mm in diameter, with longitudinal striations, scars, and lenticels. It is brown, has a short greenish fracture, and tastes bitter. The flowers are bisexual, bluish-purple, with prickly sepals, and purple deltoid lobes. Leaves are ovate-oblong, 4–12 cm long, greenish-yellow, with sharp prickles. The stem is cylindrical, spiny, and yellowish-green, while the fruit is a bitter, globular berry, green with stripes turning yellow when ripe.

Discussion: The distinct macroscopic and microscopic features of *S. xanthocarpum* Schrad. & J.C. Wendl. aid in its accurate identification. Key traits include its cylindrical, branched root; bisexual, bluish-purple flowers; ovate-oblong, prickly leaves; spiny, yellowish-green stem; and globular, striped-to-yellow, bitter fruit.

Conclusion: The study successfully achieved its aim by providing a comprehensive macroscopic and microscopic analysis of S. xanthocarpum Schrad. & J.C. Wendl. This detailed morphological and anatomical profile supports its traditional medicinal use and lays the groundwork for future pharmacological studies in Ayurveda and Modern Science.

1. INTRODUCTION

Solanum xanthocarpum Schrad. & J.C. Wendl., commonly known as yellow-fruit nightshade or *Kantakari*[1,2] in Ayurveda, is a significant medicinal plant renowned for its wide array of therapeutic applications. This plant is extensively utilized in traditional medicine systems, particularly in Ayurveda, due to its potent properties and actions. Its roots, leaves, petioles, seeds, and fruits are employed in various formulations to treat respiratory, urinary, and digestive ailments, among others. The macroscopic and microscopic features of *S. xanthocarpum* Schrad. & J.C. Wendl. play a crucial role in its identification, quality control, and authentication in pharmacognosy. Macroscopic examination involves the observation of physical characteristics such as size, shape, color, and texture of different plant parts. These features are essential for the initial identification and assessment of plant material. Microscopic analysis, on the other hand, delves into the cellular structure and arrangement, revealing intricate details such as vascular bundles, trichomes, and stomatal patterns. This level of analysis is vital for ensuring the purity and potency of the

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plant material used in medicinal preparations. In addition to modern scientific approaches, understanding the Ayurvedic perspective of *S. xanthocarpum* Schrad. & J.C. Wendl. enriches our knowledge of its medicinal value. In Ayurveda, this plant is classified as having *Vata* and *Kapha* pacifying properties, and it is traditionally used for its expectorant, anti-inflammatory, and diuretic actions. These properties make it a valuable resource in managing conditions, such as asthma, bronchitis, and various other respiratory and urinary disorders. This study aims to provide a detailed examination of both the macroscopic and microscopic features of *S. xanthocarpum* Schrad. & J.C. Wendl.

2. MATERIALS AND METHODS

2.1. Plant Material Collection

The plant parts of *S. xanthocarpum* Schrad. & J.C. Wendl. (root, leaf, petiole, seed, and fruit) were freshly collected from the campus of Shri Dhanwantry Ayurvedic College and Hospital, Chandigarh (Herbal Garden), in February 2024. The plant was washed under running tap water and blotted dry [Figure 1].

2.2. Macroscopic Examination

The macroscopic examination involved the following steps:

2.2.1. Visual inspection

Each part of the plant was visually inspected for its external characteristics, such as color, shape, size, and texture [Figure 2].

2.2.2. Odor assessment

The distinctive smells of the plant parts were noted to aid in their identification. Texture Evaluation: The texture and consistency of each plant part were evaluated by touch.

2.2.3. Foreign matter check

The samples were checked for the presence of any foreign matter to ensure purity and quality.

2.3. Microscopic Examination

Microscopic examination involved preparing transverse sections of the root, leaf, petiole, seed, and fruit using the following steps:

2.3.1. Selection of specimen

Suitable samples of the root, leaf, petiole, seed, and fruit were chosen for sectioning [Figures 3-9].

2.3.2. Softening

The specimens were softened by soaking them in water for 24 h to facilitate sectioning.

2.3.3. Sectioning

Thin, even sections of the specimens were cut using a sharp blade. The thickness of the sections was adjusted as needed [Figure 10].

2.3.4. Mounting

The sections were transferred onto glass slides and mounted, ensuring proper arrangement without overlapping [Figures 11 and 12].

2.3.5. Drying

The mounted sections were allowed to dry thoroughly before staining [Figures 13-16].

2.3.6. Staining

The sections were stained using safranine to enhance contrast and visualize specific structures.

2.3.7. Cover-slipping

A coverslip was placed over the stained sections using a suitable mounting medium to protect them and improve clarity for microscopic examination.

2.3.8. Labeling and documentation

The slides were labeled with relevant information, including the plant part and staining details.

2.4. Organoleptic Evaluation

The organoleptic evaluation was conducted to assess the sensory properties (color, odor, taste, and texture) of each plant part.

2.5. Photomicrography

Photomicrographs of the stained sections were taken using a compound microscope equipped with a digital camera. These images were used to document and analyze the cellular structures and arrangements.

2.6. Data Analysis

The macroscopic and microscopic features observed were compared with the standards provided in the Quality Standards of Indian Medicinal Plants.[10] Any deviations were noted, and the data were analyzed to determine the quality, authenticity, and suitability of the *S. xanthocarpum* Schrad. & J.C. Wendl. samples for medicinal applications.

2.7. Statistical Analysis

Descriptive statistics were used to summarize the findings, and the data were presented in tabular and graphical forms where applicable.

This comprehensive analysis of the macroscopic and microscopic features of *S. xanthocarpum* Schrad. & J.C. Wendl. provided valuable insight into the identification, quality control, and effective utilization of this medicinal plant.

A literary review from various Ayurvedic *Nighatus* was considered to know the various properties and synonyms of *Kantakari*.

3. RESULTS

Various Ayurvedic *nighantus* were also being reviewed for knowing the exact properties and synonyms of *Kantakari* that are enlisted:

The macroscopic structures were almost similar when compared with the Quality Standards of the Indian Medicinal Plant, the only difference was shown that the fractured surface was whitish and only a few rootlet scars were present. When flowers were compared then all the features were found to be similar to that of the standard features, i.e., purplish flowers with persistent calyx. Leaves were sinuate, sub-acute, midrib and lateral veins showed prominent sharpe prickles, petiole was cylindrical, and all the macroscopic features were similar to the standard the only difference was found that the upper and lower surfaces were green and odorless. Microscopic structures through the midrib are dorsiventrally convex and show a narrow collenchymatous band underneath both epidermis, but it was not distinct. The stem was found to be cylindrical slightly angular and variable in length, the surface is spiny running longitudinally running winged extension. Internodes were 10 cm in length, fracture showed hollow in the center, and taste was bitter. Microscopy of the stem shows a ring of bicollateral stele, and perimedullary fibers encircling the central pith which becomes hollow in the mature stem. The fruit was a globular, bicarpellary berry with persistent spines These are shown in tables 2-8. This helps in the

accurate identification of *Kantakari,* i.e. *S. xanthocarpum* Schrad. & J.C. Wendl. as in Ayurveda, various other plants are also known with the name of *Kantakari.*

From various Ayurvedic *nighantus*, *Kantakari* (*S. xanthocarpum* Schrad. & J.C. Wendl.) is a common plant available everywhere straggling (*dhavani*), thorny (*kantakari, kantakini*) difficult to touch (*duhasparsha*), with small and variegated fruits (*ksudraphala, citraphala*) and growing fastly (*nidigdhika*). It liquefies *kapha*, alleviates cough (*kasaghni*), obesity, mucous coating (*nidigdhika*), diseases of nose, etc., and promotes voice (*vyaghri*). Thus, *Kantakari* is actually (*kanthakai*) (wholesome for throat) and as such included in *kanthya* group [Tables 1 and 9].[16]

These findings provide a comprehensive morphological and anatomical profile of *S. xanthocarpum* Schrad. & J.C. Wendl., essential for accurate identification and potential pharmacological studies.

4. DISCUSSION

S. xanthocarpum Schrad. & J.C. Wendl., commonly known as yellow-berried nightshade, can be accurately identified through its distinctive macroscopic and microscopic features. The root of the plant is cylindrical and branched, providing a sturdy foundation. The stem is spiny and yellowish-green, adding to the plant's unique appearance. The leaves are ovate-oblong in shape and covered with prickles, making them easily recognizable.

One of the standout features of *S. xanthocarpum* is its flowers. The plant produces bisexual flowers that are bluish-purple, a colour that sets them apart from many other species. These flowers contribute to the plant's reproductive capability, ensuring its propagation.

The fruit of *S. xanthocarpum* is another key characteristic. It is globular in shape and transitions from striped to yellow as it matures. The fruit has a bitter taste, which can be a distinguishing factor. This combination of features, from the spiny stem and prickly leaves to the vibrant flowers and distinctive fruit, allows for the precise identification of *S. xanthocarpum*. These traits are critical for botanists and herbalists who rely on accurate plant identification for research, medicinal uses, and ecological studies, ensuring that *S. xanthocarpum* can be correctly distinguished from similar species.

5. CONCLUSION

The study successfully achieved its aim by providing a comprehensive macroscopic and microscopic analysis of *S. xanthocarpum* Schrad. & J.C. Wendl. The detailed observations of the root, leaf, flower, stem, and fruit, along with their distinctive features, aid in the accurate identification of this significant medicinal plant. The findings include the presence of vascular bundles, trichomes, and stomatal patterns, which are crucial for quality control and authentication in pharmacognosy. *Kantakari*, a common plant from Ayurvedic *nighantus*, is thorny, difficult to touch, and has small, variegated fruits. It liquefies kapha, alleviates cough, obesity, and nose diseases, and promotes voice. A comprehensive morphological and anatomical profile is essential for identification and pharmacological studies. This thorough examination and literary review support the traditional medicinal use of *S. xanthocarpum* Schrad. & J.C. Wendl. and lays the groundwork for future pharmacological studies in Ayurvedic *Nighatus*.

6. ACKNOWLEDGMENTS

Nil.

7. AUTHORS' CONTRIBUTIONS

All the authors contributed equally in the design and execution of the article.

8. FUNDING

Nil.

9. ETHICAL APPROVALS

This study is not required ethical clearance.

10. CONFLICTS OF INTEREST

Nil.

11. DATA AVAILABILITY

This is an original manuscript and all data are available for only review purposes from principal investigators.

12. PUBLISHERS NOTE

This journal remains neutral with regard to jurisdictional claims in published institutional affiliation.

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Figure 1: *Solanum xanthocarpum* Schrad. & J.C. Wendl. Whole plant

Figure 2: *Solanum xanthocarpum* Schrad. & J.C. Wendl. Whole plant

Figure 3: *Solanum xanthocarpum* Schrad. & J.C. Wendl. Flowers and Leaves

Figure 4: Arrangement of Stamens (Epipetalous)

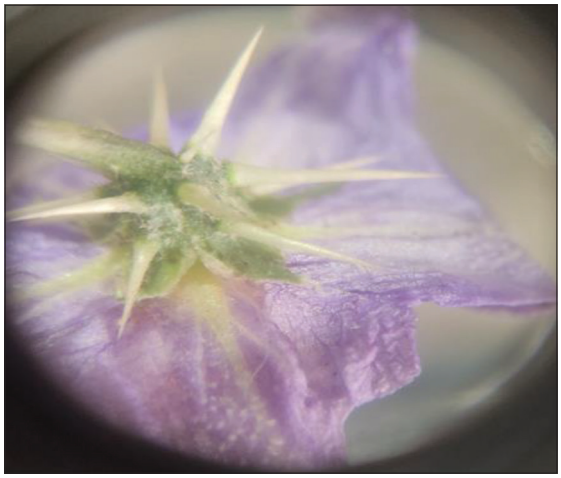

Figure 5: Persistent calyx

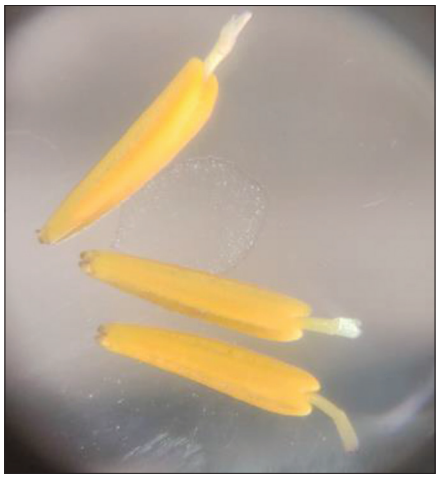

Figure 6: Stamen

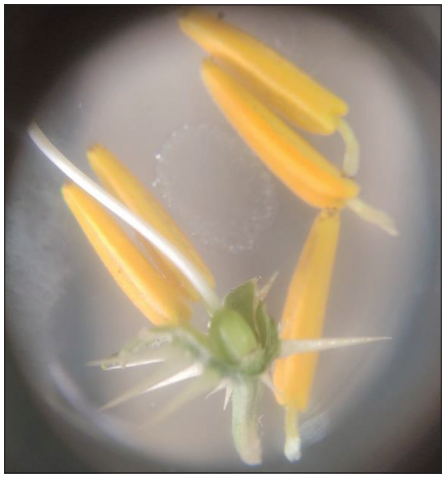

Figure 7: Stamens with carpel

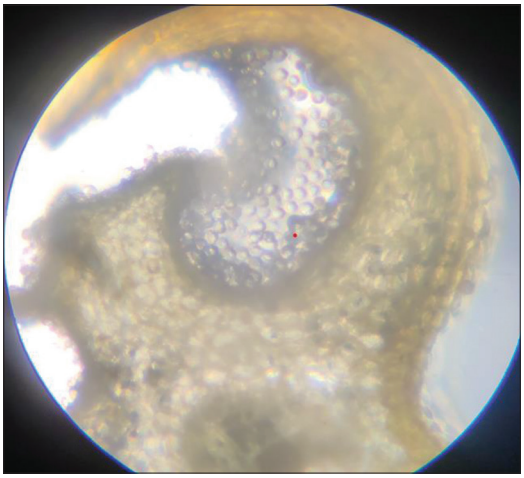

Figure 8: Transverse section of Stamen

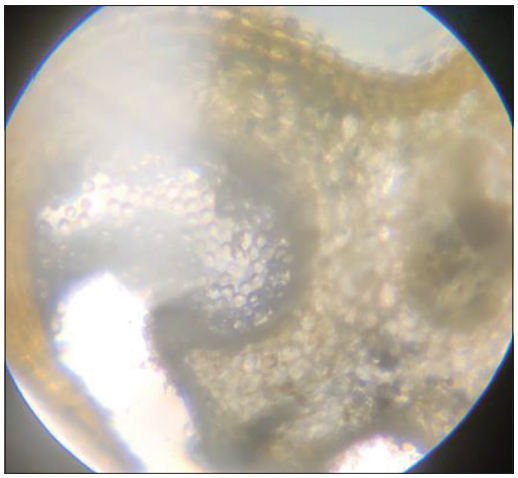

Figure 9: Transverse section of Stamen

Figure 10: *Solanum xanthocarpum* Schrad. & J.C. Wendl. Leaf

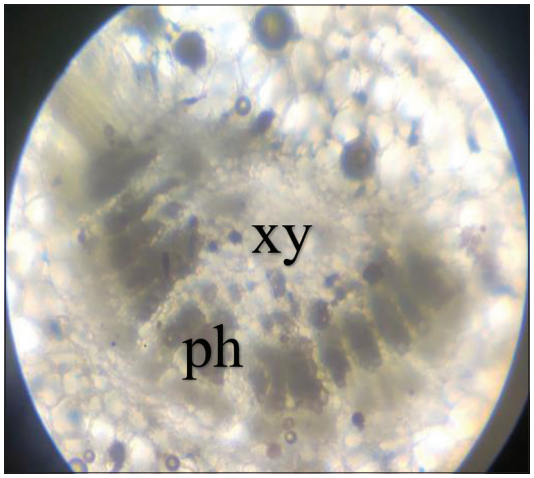

Figure 11: Transverse section of *Solanum xanthocarpum* Schrad. & J.C. Wendl. Leaf showing xy - xylem, ph - phloem, pa - parenchyma, scr -nsandy crystals of calcium oxalate, col - collenchyma

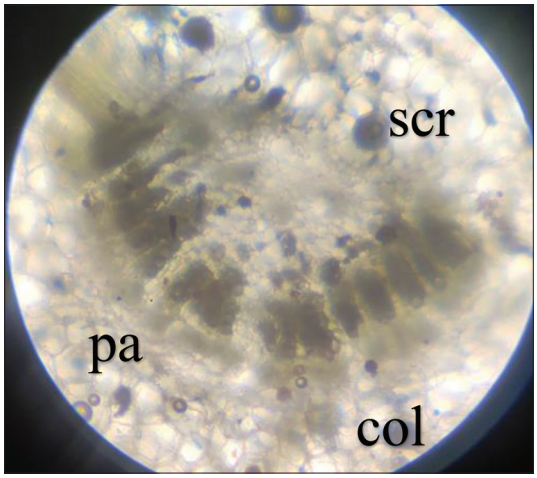

Figure 12: Transverse section of *Solanum xanthocarpum* Schrad. & J.C. Wendl. Leaf showing xy-xylem, ph-phloem, pa-parenchyma, scr-nsandy crystals of calcium oxalate, col-collenchyma

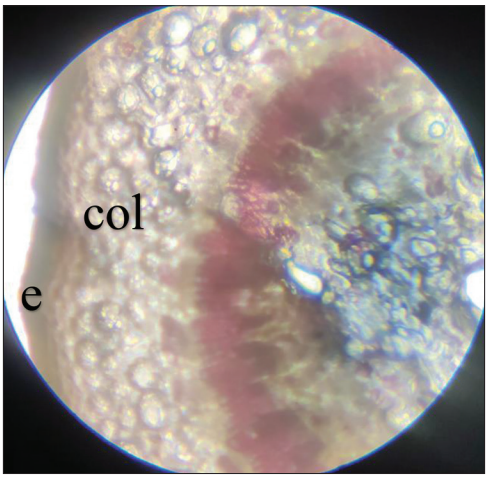

Figure 13: Col-collnchyma; e - epidermis; ph - phloem; phf - phloem fibres; pi - pith; wg- wing; xy - xylem

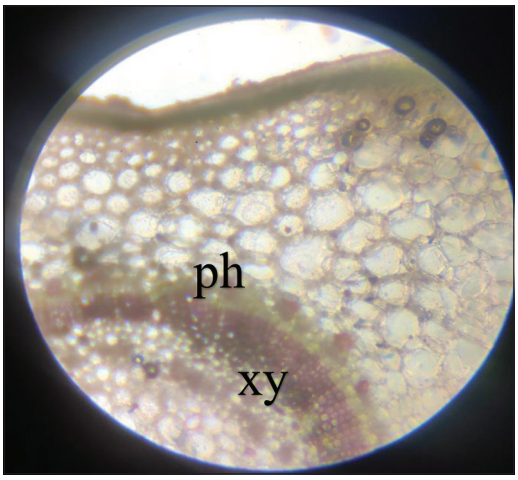

Figure 14: Col-collnchyma; e - epidermis; ph - phloem; phf - phloem fibres; pi - pith; wg- wing; xy - xylem

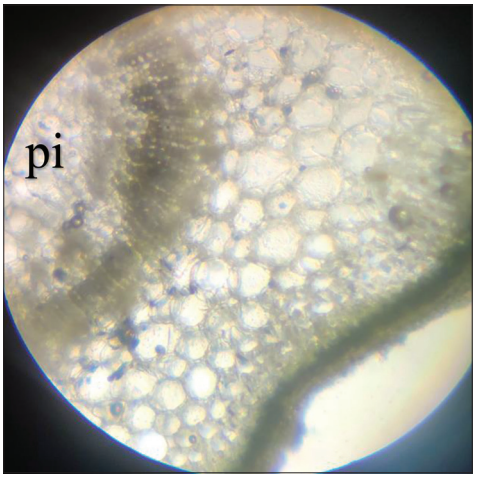

Figure 15: Col-collnchyma; e - epidermis; ph - phloem; phf - phloem fibers; pi - pith; wg- wing; xy - xylem

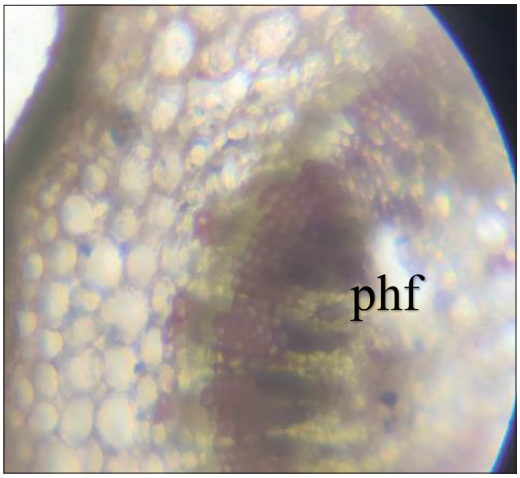

Figure 16: Col-collnchyma; e - epidermis; ph - phloem; phf - phloem fibers; pi - pith; wg- wing; xy - xylem

Table 1: Recent research on *S. xanthocarpum* Schrad. & J.C. Wendl

Action/Karma	Site of action	Type of study	Description
Rajayakshma/ Paratuberculosis[3]	*Tridoshaghna, Sarvaroga Jita, Brimhana, Swasa, Kasa, Balya*	*In vitro* anti-mycobacterial activity	Bioactive compounds from *Ocimum sanctum* and *S. xanthocarpum* were evaluated for anti-MAP activity. Ursolic acid (12 µg/mL) and solasodine (60 µg/mL) showed suitable MIC50 values
Pramehaghna/ hypoglycemic activity[4]	*Medahara, Kaphahara*	*In vivo* and *in vitro* study	The aqueous extract of *S. xanthocarpum* fruits has significant hypoglycemic activity, comparable to glibenclamide. *In vitro* studies on isolated rat hemidiaphragm suggest that this extract may have insulin-like activity, enhancing peripheral glucose utilization, and exerting extra-pancreatic effects
Pleharoga/ hepatoprotective activity[5]	*Raktavaha srotas*	*In vivo* study	Ethanolic fruit extract of *S. xanthocarpum* (100, 200, and 400 mg/kg bw) was administered daily for 35 days to experimental animals with liver toxicity induced by antitubercular drugs (isoniazid, rifampicin, and pyrazinamide). The treatment significantly (P<0.05–P<0.001) and dose-dependently prevented the drug-induced increase in serum hepatic enzymes, reduced liver LPO, and restored antioxidant enzyme activities (GSH, SOD, and CAT) toward normal levels. Histopathology showed reduced hepatocellular necrosis and inflammatory cell infiltration
Antipyretic Activity/ *Jwaragna*[6]	*Rasavaha srotas*	*In vitro* (laboratory-based bioassay)	Larvicidal activity was tested against early-stage larvae of *Anopheles stephensi*, Aedes aegypti, and *Culex quinquefasciatus* at 20-–120 ppm, with *Culex quinquefasciatus* being the most susceptible. GC-MS analysis identified 43 compounds, including major ones such as phytol (13.09%), 3-allyl-2-methoxy phenol (9.55%), and linoleic acid (5.45%)
Chronic autoimmune condition/ Anti-psoriatic[7]	*Raktavaha srotas*	Molecular docking	According to the IMPPAT Database, 8 active compounds from SX were effective against PSO. PPI network and core targets study identified key targets: EGFR, SRC, STAT3, ERBB2, PTK2, SYK, EP300, CBL, TP53, and AR. Molecular docking simulations confirmed the binding interactions of SX phytochemicals with these PSO targets
Anti-osteoarthritic[8]	*Asthivaha srotas*	*In vitro* and *in vivo*	Histological studies showed that SXF restored collagen and proteoglycan synthesis, essential for cartilage restoration, and reduced the arthritic score
Wound healing in Diabetic rats[9]	*Medovaha srotas* and *raktavaha srotas*	*In vivo*	The extract of *S. xanthocarpum* mainly contained alkaloids, polyphenols, and steroids, with chlorogenic acid at 8.44% w/w. The extract was most effective in healing at 10% gel (topically) and 200 mg/kg (orally) in diabetic rats, with the best results observed when used both orally and topically

S. xanthocarpum: *Solanum xanthocarpum*, GSH: Glutathione, SOD: Superoxide dismutase, CAT: Catalase, LPO: Lipid peroxidation, GC-MS: Gas chromatography–mass spectrometry, EGFR: Estimated glomerular filtration rate

Table 2: Macroscopic features *Solanum xanthocarpum* Schrad. & J.C. Wendl. Root

Features	Observations
Shape	Cylindrical, branched, long, tapering gradually
Size	5–8 mm in diameter, variable in length
Surface	Longitudinally striated with scars and lenticels present
Odor	Nil
Fracture	Short, surface-greenish
Color	Brown
Taste	Bitter

Table 3: Macroscopic features *Solanum xanthocarpum* Schrad. & J.C. Wendl. Flowers

Features	Observations
Calyx	Bisexual, pedicellate, actinomorphic, bluish-purple in color
	Persistent, sepals-1cm, densely prickly
Corolla	Lobe's deltoid, purple colored
Androecium	Stamens 5, epipetalous Anther - oblong, 0.8 cm long, yellow colored
Gynoecium	Ovary - superior, ovoid, bilocular with numerous ovules

Table 4: Macroscopic features *Solanum xanthocarpum* Schrad. & J.C. Wendl. Leaf

Features	Observations
Shape	Ovate oblong, sinuate, sub-acute, pubescent, Petiole – cylindrical
Size	4–12 cm in length, 2.5–5 cm width Petiole - 1–3 cm
Surface	Leaf midrib and lateral veins show sharp prickles Petiole - Persistent with spines
Odor	Not characteristic
Color	Greenish yellow
Taste	Not characteristic

Table 5: Microscopic features *Solanum xanthocarpum* Schrad. & J.C. Wendl. Leaf

Features	Observations
Upper epidermis and Lower epidermis	Embedded with stomata, trichomes present
Chollenchymatous bands	Underneath both epidermis
Meristele	Centrally located Embedded in parenchymatous ground tissue Microsphenoidal crystals present in parenchymatous cells
Lamina	Rows of palisades underneath the upper epidermis, 4–6 rows of spongy parenchymatous tissues present.

Table 6: Macroscopic features *Solanum xanthocarpum* Schrad. & J.C. Wendl. Stem

Features	Observations
Shape	Cylindrical, slightly angular
Size	5–10 mm in diameter, variable in length
Surface	Spiny
Fracture	Fibrous
Color	Yellowish-green surface
Taste	Bitter

Table 7: Microscopic features *Solanum xanthocarpum* Schrad. & J.C. Wendl. Stem

Features	Observations
Epidermis	Embedded with stomata Glandular trichomes are present
Hypodermis	Collenchymatous narrow band
Cortex	Parenchymatous
Phloem and Xylem	Sieve tissue, phloem parenchyma, uni- biseriate medullary rays in continuation with xylem. Radially arranged xylem vessels. Distinct cambium Present
Pith	Parenchymatous Disintegrated in older stem - centrally located hollow pith.
Starch grains	Present

Table 8: Macroscopic *Solanum xanthocarpum* Schrad. & J.C. Wendl. Fruit

Features	Observations
Shape	Globular, bicarpellary berry with persistent spines
Size	1 cm in diameter
Surface	Smooth
Color	Green when young, with green-white stripes present turning yellow when ripe
Taste	Bitter

Table 9: *Nighantu* description of various synonyms of *Kantakari* by B.P - *Bhavaprakasha Nighantu*, K.N - *Keydeva Nighantu*, M.P - *Madanapala Nighantu*, S.N - *Sadarasa Nighantu*, D.N. - *Dhanwantry Nighnatu*

Synonyms	B.P[11]	K.N[12]	M.P[13]	S.N[14]	D.N.[15]
Kantakari	+	+	+		+
Kantakini	+	+			
Duhasparsha	+	+	+	+	+
Duspradharshini		+			
Kshudra	+	+		+	+
Nidigdhika	+	+	+	+	+
Dhavini	+	+	+	+	+
Kshudrakantika		+			
Bahukantha		+		+	
Kshudrakantha		+			
Kshudraphala		+			
Kantarika		+	+		
Chitraphala		+			
Vyaghri	+		+	+	+
Kantalika	+				+
Brihati	+				
Kantakini			+	+	+
Kantakarika				+	
Singhi				+	