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EUPHORBIA FUSIFORMIS: A RARE, VERSATILE SPECIES - A REVIEW

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ABSTRACT: *Euphorbia fusiformis* Buch.-Ham.ex D. Don, (Synonym: *Euphorbia acaulis* Roxb) is an infrequent, medicinal, geophytic herb of the family Euphorbiaceae. It is distributed only in few pockets of India, Nepal, Africa and China. In India, it is found to grow in Maharashtra, Karnataka, Gujarat, Goa, Rajasthan, Andhra Pradesh, Madhya Pradesh, Uttar Pradesh, Bihar, Tamil Nadu and West Bengal. Traditionally, local tribal people of India had been using this plant to treat headache, arthritis, gout, paralysis, diarrhoea, abdominal diseases, abdominal tumor, liver disorders, urinary stones, chronic wound cracks, skin disease, eczema and poor lactation. In scorpion and snake bites, plant latex was used as an antidote. Phytochemical analysis of the plant demonstrated the presence of number of primary and secondary metabolites such as flavonoid, phenol, proteins, saponin, phytosterol, triterpenoids, fixed oil and fats. It also contains vitamin C, vitamin E, and minerals. Some of the important phytoconstituents found in roots of *Euphorbia fusiformis* are Caudicifolin, Ellagic acid, 3, 3'-di-O methylellagic acid and Euphol. Sesquiterpenes, aliphatic compounds and small amount of monoterpenes are mainly found in oil. It has been reported that *E. fusiformis* possess variety of pharmacological activities like antioxidant, antifungal, diuretic, anti-inflammatory, antibacterial, hepato-protective, antinociceptive, and galactagogue. Also the plant is being evaluated for its use in female infertility. In this review, an attempt has been made to compile comprehensive updated information of *Euphorbia fusiformis*.

INTRODUCTION: Many of the medicinal plant species are much less explored because of their limited geographical distribution. One of them is *Euphorbia fusiformis* Buch.-Ham. Ex D. Don, scattered in few regions of countries like India, Nepal, Africa and China [1, 2].

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Its occurrence in India is limited to few localities of Maharashtra, Uttar Pradesh, Karnataka, Tamil Nadu, Nagar Haveli, Telangana State, Andhra Pradesh, and West Bengal [3, 4, 5]. *Euphorbia fusiformis* belongs to a big family Euphorbiaceae, with about 8000 species and 300 genera throughout the world and about 195 species in India [6, 7, 8].

Euphorbia fusiformis is a rare, perennial, succulent, acaulescent, scapigerous herb grown up to 20 cm to 25 cm below the ground. The species name is because of its fusiform root. It has long root narrowing towards both ends and has no visible above-ground stem.

It belongs to the subgenus Rhizanthium. Leaf flushing occurs straight from the tip of the taproot, specifically during monsoon per year.

Leaves are the only above-ground vegetative part of this plant. Flowers develop after shedding all leaves from March to May [1].

The Ethnomedicinal importance of this plant is because of its use to treat arthritis, gout, paralysis, liver disorders, abdominal tumor, abdominal diseases, diarrhoea, chronic wounds, skin disease, headache, poor lactation, and eczema [1, 9].

The phytochemical profile reveals that caudicifolin, methylellagic acid, and euphol are present as main constituents in *Euphorbia fusiformis* [10]. The reported pharmacological activities of *Euphorbia fusiformis* are antioxidant, antifungal, diuretic, anti-inflammatory, antibacterial, hepatoprotective, antinociceptive, and galactagogue.

It has been observed that it increases intestinal transit time; also, the plant is being evaluated for its use in reversing female infertility [2, 3, 12-30].

In spite of the versatile traditional uses of this species, its population is endangered because of the localized distribution and stunted vegetative growth. Thus conservation is required to raise its populace and to decrease the risk for demands [1, 31, 32].

Botanical Description: *Euphorbia fusiformis* Buch.-Ham. exD. Don

Taxonomy: [33, 34]

TABLE 1: TAXONOMICAL CLASSIFICATION OF *EUPHORBIA FUSIFORMIS*

Kingdom	Plantae
Subkingdom	Viridiplantae
Infrakingdom	Strptophyta
Superdivision	Embryophyta
Division	Tracheophyta
Subdivision	Spermatophytina
Class	Magnoliopsida
Superorder	Rosanae
Order	Malpighiales
Family	Euphorbiaceae
Subfamily	Euphorbioideae
Tribus	Euphorbiaceae
Subtribus	Euphorbiinae
Genus	Euphorbia L.-Spurge
Species	fusiformis Buch.-Ham. ex D. Don

Local Names: [35-52]

- Maharashtra: Bhuiphod, Chirkandichakanda
- Andhra Pradesh: Barrasapugaddalu, Palachepugaddalu
- Rajasthan: Pahari mooli, Kargosh ra kandoo, Mooli
- Odisha: Dudhi; Deri-chuwa Khirakanchana, Birmuli
- Gujarat: Khurkund
- Madhya Pradesh: Khargoni
- Uttar Pradesh: Banmuli
- West Bengal: Dhudhmul

Synonyms: [53, 54]

TABLE 2: SYNONYMS OF *EUPHORBIA FUSIFORMIS*

Species name	Synonym	Variety
Euphorbia fusiformis Buch.-Ham. Ex D. Don.	*Euphorbia acaulis* Roxburgh *Euphorbia nana* *Euphorbia humilis* *Euphorbia seshachalamensis*	*Euphorbia khandalensis* Euphorbia *panchganiensis.*
The species first described by D.Don in 1825 and named after F. Buchanan-Hamilton who collected the specimen in Nepal	W. Roxburgh in 1832 and Cooke in 1906 described the specimens *Euphorbia acaulis*, collected from the eastern Himalayan foothills and from the Western Ghats of Maharashtra State respectively. J. F. Royle in 1836 added *Euphorbia nana* and *Euphorbia humilis* considering his own collections from the Himalayan foothills. Recently in 2016, *Euphorbia seshachalamensis*, observed from Sheshachalam hills of Andhra Pradesh has been described by K. Prasad & Prasanna and can be considered as synonym of *E. fusiformis*.	In 1921, the species obtained from western Ghats and south-western plateau of Maharashtra, nearby Pachagani and Mahabaleshwar named *Euphorbia khandalensis* and *Euphorbia panchganiensis* respectively. *E. panchganiensis* was considered as Synonym of *E. nana*, and *E. khandallensis* was considered as a variety of *E. fusiformis*

Geographic Distribution And Ecology: The succulent geophytic herb, *Euphorbia fusiformis* Buch.-Ham. ex D. Don had its confined distribution in countries like India, Nepal China and Africa [1, 2].

In India, distribution of this species is only in a few localities of Maharashtra, Karnataka, Gujarat, Rajasthan, Nagar Haveli, Bihar, Goa, Tamil Nadu, Madhya Pradesh, Andhra Pradesh and West Bengal is reported [3]. It has also been observed in Tropical Himalayas upto 1500 feet where it extends from Garhawal to Nepal [10, 28, 55, 56, 57].

In Maharashtra state, it is found at Khandalla, Lonavala, Bhimashankar, Pachagani, Mahabaleshwar, Karjat, Deccan hills , Purandhar hills of Pune district, Southwestern plateau of Satara district and Konkan regions in Sindhudurg district [3]. In the state of Gujarat it is found in Dang, Rajpippala and Chotaudaipur [10]. In Karnataka the species is found in dry deciduous forests foothills of Gopalswamy hill of Chamarajanagara district, Bababudangiri of Chikkamagalore district Bannerghatta of Bangalore and Belekal Betta of Ramanagara district, Gudekote of Kudlungi taluka of Bellary district [58].Whereas a single patch of this plant in the lateritic floor of Gonpur district of west Bengal was observed [1].

Euphorbia fusiformis is generally observed on open flat hill slopes amongst grasses and along the margins of moist deciduous forests. A well-drained soil is good for growing of this plant. It is not generally found on lower slopes. The plant is rarely cultivated as the growth rate is slow. Sufficient amount of water and nutrients can speed up growth. Excess of water can cause decay of the plant [58].

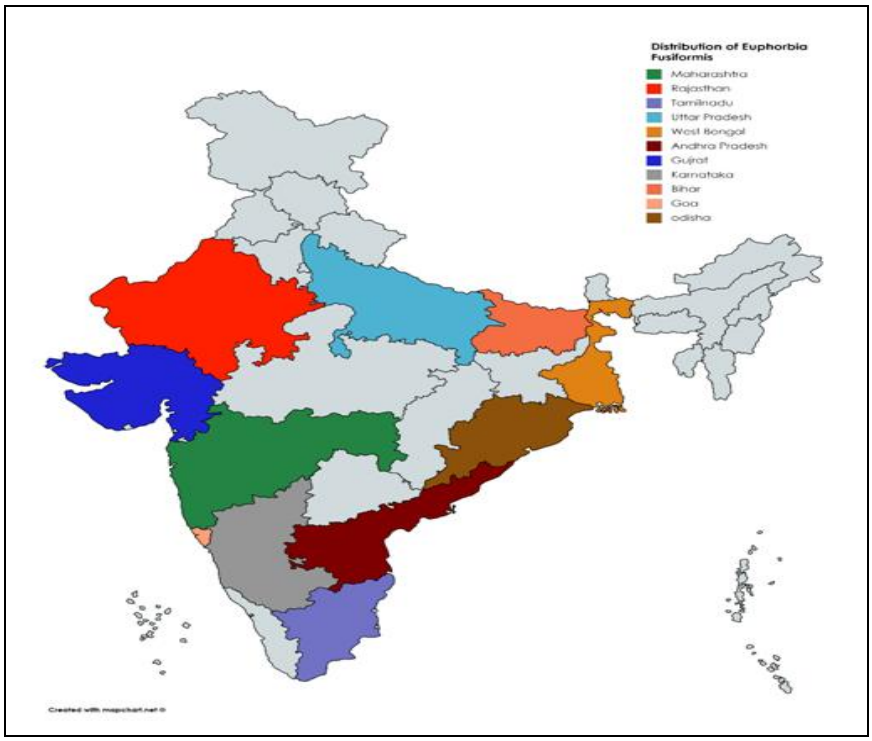


FIG. 1: GEOGRAPHIC DISTRIBUTION OF *EUPHORBIA FUSIFORMIS* IN INDIA [59]

Morphology: [8]

Rootstock: It is cylindrical, fusiform buried in the ground. The main tuber is about 30-80 cm long and 4-7 cm in diameter with 3-6 number of secondary roots measuring 0.3-9.0 cm emerging near the apex in all directions below soil level. It contains milky latex.

Leaves: Mostly green, 5-15 cm long 1-4 cm broad, generally are 1-6 in number. They are succulent, glabrous, and petiolate, broadly to narrowly lanceolate-oblanceolate. The midrib is prominent on the ventral side whereas lateral nerves are indistinct. Leaves are slightly fleshy, lactiferous with an undulate margin attenuated at the base; leaves are curled or entire or along the margin, atapexacute, and mucronate.

Inflorescence: appears during February-April after leaf fall. It is cyme, yellow-green-pinkish, 3-4 cm

long, glabrous, pedunculate. It is dichotomously branched, cyathia appearing before leaves bisexual, in diads or triads cyathial glands oblong. Male flowers appear before the female. Male florets are in three or four fascicles, each with 3-4 florets.

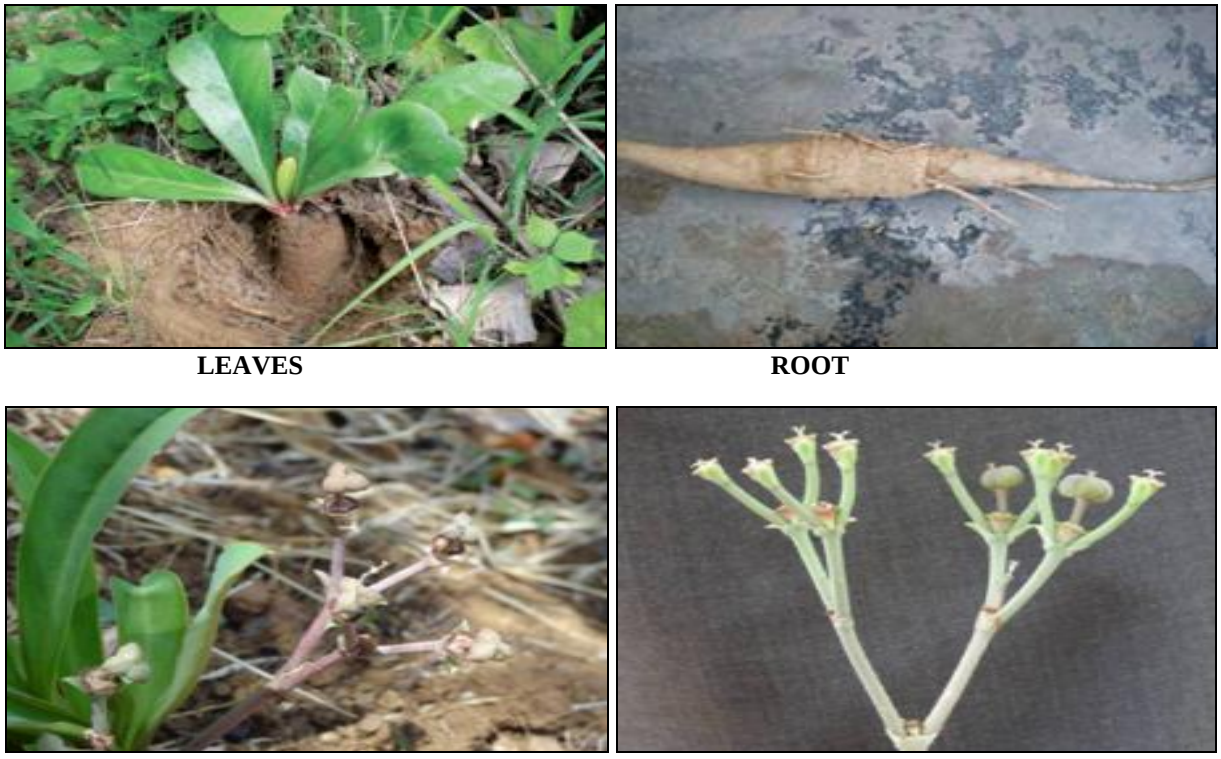
Female florets: gynophores 2-4 mm long: ovary trilocular, subglobose; styles 3 connate at base, stigma lobed, papillose Sometimes deep red patches are present on female florets present when the climatic condition is very dry. Stamens 2-5 mm long, capsule, slightly rounded glabrous and greenish. Petioles 2-4.5 cm long red in colour. Primary peduncles 1-3 cm from the apex of the rootstock, secondary or tertiary peduncles 1.5-3 cm long; involucre turbinate, 5 lobed.

Lobes are sub obovate, laciniate along apical margin. Glands are, reddish or greenish pink, transversely oblong.

Fruits: capsular, 3 lobed, 4-6 mm in diameter, very dark grey in color mottled with white.

Generally 3 seeds, ovate or nearly oblong, smooth and globose are present.

Flowering and Fruiting Time: March to May



LEAVES **ROOT**

FRUITS **EFFLORESCENCE**

FIG. 2: LEAVES, ROOT, FRUITS AND EFFLORESCENCE OF *EUPHORBIA FUSIFORMIS* [3]

Microscopy: Transverse section of tuberous root shows secondary growth and is circular. The outer cork layer is slight brownish and consists of tubular cells. There is 8-9 layered inner cork followed by layer of rectangular-shaped parenchymatous cells.

A cork cambium and large cortex, of parenchymatous cells, are also present. Starch grains are present in clusters, and Laticifers cells are scattered in the cortical region. Xylem elements are prominent, whereas pericycle and endodermis is not prominent. Well-developed pith shows loosely arranged parenchymatous cells. T.S of the lateral root also shows a circular outline with secondary growth. Vascular tissues and phloem element is clearly visible unlike the tuberous root [58].

Ethnobotany: *E. fusiformis* has ethnobotanical importance as it serves as a remedy for several diseases.

Tubers:

- At Kanakapura of Ramanagara district, Karnataka state Vaidyas used aqueous solution of fresh tuberous roots to increase the milk production in lactating mother. It's been given orally for about a week, three times a day. Also, the paste of tubers is given internally for

cows and cattle to improve the milk yield. The tribal community of Gonpur forest in West Bengal also had used *Euphorbia fusiformis* to improve poor lactation [2, 38, 60]

- In Ethnoveterinary medicine, the tubers of this plant were used for treating Ephemeral fever in livestock by Vaidyas of Andhra Pradesh. 200 g. of tuber paste mixed with sufficient quantity of garlic powder and pepper is administered twice daily for three days to the livestock [50].
- In some regions of the Himalayas, the pulp of the tuber was used for relieving pain and inflammation from arthritis [3]. The rootstock paste admixed with mustard oil as the external application is the potential remedy for arthritis, paralysis, and gout [4, 41]. The rootstock is used by tribal of Uttar Pradesh and Madhya Pradesh in gout, rheumatism, fever, and dysentery [55].
- The tuber, when crushed with rice and taken during 3rd and 5th day of the menstrual cycle, acts as a contraceptive for one month [61].
- Rhizome Powder is used to cure Hydrocele, High blood pressure, and sperm debility [44, 45].
- Root Powder is eaten to get relief from constipation [47].
- The root paste is given orally to animals to cure dysentery and fever for two times a day for 3 to 5 days [50].

Latex:

- The latex of this plant acts as an antidote and it was used to counteract the poisoning caused by snake or scorpion bites [62].
- It had been used to treat liver disorders, diarrhea, chronic wounds, and skin diseases. It is helpful for burning off warts and eczema [2, 12, 62].

Leaves:

- Paste of the leaves, when applied to the fore-head, provides relief from acute headaches [12, 26].
- The roots and leaves of this plant can be used to treat ephemeral fever [4, 48]
- Leaf Juice had been used for the treatment of burn [51].

Analytical Studies: To perform analytical studies, matured tuberous roots were collected, sliced and shade dried.

Powdered and sieved dried material used for studies like organoleptic study, phytochemical analysis, powder analysis using different chemicals, and fluorescence analysis under UV-Chamber. All analytical studies were performed using standard procedures. The dry powder was stored under an air-tight container [55].

Organoleptic studies can be used in the authentication of the crude drug. Results of Physico-chemical parameters, powder analysis, fluorescence analysis also helps in the correct identification of the crude drug.

Powder analysis with different chemical agents gives the end color, which is more or less brown. Fluorescence analysis of the dried powder performed with respect to visible light and short-wavelength shows less variation in colour [55].

TABLE 3: ORGANOLEPTIC STUDY OF *E. FUSIFORMIS* ROOT POWDER [44]

S. no.	Feature	Observation
1	Nature	Coarse Powder
2	Color	Brown Color
3	Odour	No characteristic Odour
4	Taste	Tasteless

TABLE 4: PHYSICO-CHEMICAL PARAMETERS OF ROOTS OF *E. FUSIFORMIS* [10]

S. no.	Parameter	Result (% w/w)
1	Loss on drying at 105 ºC	11.50
2	Total ash value	7
3	Acid insoluble ash	0.6
4	Water insoluble ash	4
5	Water soluble extractive	8.38
6	Methanol soluble extractive	5.56
7	P^H	6.9
8	Foreign matter	0.3

TABLE 5: POWDER ANALYSIS OF *E. FUSIFORMIS* ROOT POWDER [58]

S. no.	Reagent	Color observed
1	Powder as such	Brown
2	Powder +conc HCl	Brown
3	Powder +Ammonia	Brown
4	Powder +5% Na OH	Brown
5	Powder +5% KOH	Brown
6	Powder +Conc H_2SO_4	Light Brown
7	Powder +Glacial acetic acid	Light Yellowish Brown
8	Powder +Conc HNO_3	Reddish Brown

TABLE 6: FLUORESCENCE ANALYSIS *E. FUSIFORMIS* ROOT POWDER [58]

S. no.	Reagent	Visible light	Fluorescence observed	
			Short wavelength (254 nm)	Long wavelength (365 nm)
1	Powder as such	Brown	Creamy white	Creamy white
2	Powder + Methanol	Light brown	brown	brown
3	Powder+50% HCl	Brown with ppt	Brown with ppt	Light brown with ppt
4	Powder + 50% H_2SO_4	Dark brown with ppt	Light brown with ppt	Light brown with ppt
5	Powder + Chloroform	Light brown with ppt	Light brown with ppt	Light green with ppt
6	Powder +HNO_3+ NH_3	Light Brown with ppt	Brown with ppt	Light green with ppt
7	Powder +5% Iodine	Brown	Green	Green
8	Powder +1N NaOH in Water	Brown	Light green	Light green
9	Powder + Ethanol	Light white	Light brown	Light brown
10	Powder +Petrolium ether	Light white	Light brown	Light green
11	Powder + Acetic acid	Light white	Light white	Light white
12	Powder +1 N NaOH in Methanol	Light yellow	Light yellow	Light yellow
13	Powder +1 N NaOH in Ethanol	Light yellow	Light green	Light green
14	Powder + 50% HNO_3	Light yellow with ppt	Light brown with ppt	Light green with ppt

Minerals: A micro-scaled digestion using microwave was employed for the determination of accurate elemental analysis of tubers of plant. Iron was found abundantly in *Euphorbia fusiformis*. The concentration of copper was found least, whereas the Selenium was not detected [3].

TABLE 7: ELEMENTAL CONCENTRATIONS IN *EUPHORBIA FUSIFORMIS* AFTER MICRO-SCALED DIGESTION [3]

S. no.	Elements	Concentrations (ppm)
1	Zink	10.0288
2	Copper	9.2312
3	Manganese	56.1546
4	Iron	2711.736

Flavonoids Analysis by HPTLC: Flavonoid analysis of aqueous, methanol, acetone and chloroform extract of *Euphorbia fusiformis* was performed by using the High Performance Thin Layer Chromatography. **Table 8** shows the flavonoid analysis of aqueous, acetone, chloroform and methanolic extracts of *Euohorbia fusiformis* tubers [3].

The radical scavenging property (Antioxidant) and other biological activities can be attributed to flavonoids, the important and diverse phenolic compounds occurring naturally.

Determination of Vitamin E by Reverse Phase HPLC: Vitamin E concentration in the extracts was determined using the Reverse Phase HPLC technique coupled with UV detector. dl α-tocopherol acetate 96 percent, *i.e.,* Vitamin E was used for standard curve calibration. A gradient mobile phase Acetonitrile: water (95:5) was used. Detection was carried out at 220 nm. The lipophilic vitamin E has been found to be present in the *Euphorbia fusiformis* chloroform extract.

The presence of vitamin E can be correlated with significant antioxidant activity of *Euphorbia fusiformis* [3].

TABLE 8: FLAVONOID ANALYSIS OF *EUPHORBIA FUSIFORMIS* TUBER EXTRACTS UNDER 254 NM AND 366N M [3]

Plant Extract	Assigned substance at 254 nm	Assigned substance at 366 nm
Water extract	saponanin	saponanin
	Diosmin	Diosmin
	Rutin	Rutin
	Epigenin	Epigenin
	Hesperdin	Hesperdin
	Caffeic acid	Caffeic acid
	Hesperidin	Catechin
Acetone Extract	Astrangnlin	Astrangnlin
	Catechin	Catechin
	Quersetin	Quersetin
	Hesperidin	Hesperidin
Chloroform extract	Quersetin	Quersetin
	Diosmin	Hesperdin
		Epigenin
Methanol extract	Rutin	saponanin
	Hesperdin	Diosmin
	Astrangnlin	Luteoline
	Luteoline	Astrangnlin
	Phenolic acid	Phenolic acid
	Kampherol	Kampherol
	saponanin	Catechin
	Diosmin	Isoquercitin

Determination of Vitamin C: The ethanolic solution of sodium salt of 2, 6- dichlorophenol-indophenol (DCPI, 0.25%) was used for the detection of Vitamin C. 2 drops of DCPI indicator when added to 0.5 mL of sample extracts changes the blue colour to red. It confirms the presence of vitamin C. All the extracts were tested for the presence of vitamin C. The hydrophilic vitamin C was found to be present in water extract of tubers of *Euphorbia fusiformis* [3].

TABLE 9: PRELIMINARY PHYTOCHEMICAL SCREENING OF TUBER EXTRACT OF *EUPHORBIA FUSIFORMIS*

Ext	Car	Sta	Prot	Glyc	Alk	Sap	Tan	Flav	Phe	Vit C	Vit E
WE	+++	-	-	++	-	++	-	++	+	+	-
ME	++	+++	+	+	+++	+	GT+	+++	++	-	-
CE	++	-	-	+	-	-	-	+	-	-	++
AE	++	-	-	+	-	-	-	+	-	-	-

Ext = Extract, Car = Carbohydrate, Sta = Starch, Prot = Protien, Glyc = Glycoside, Alk = Alkaloids, Sap = Saponins, Tan = Tannin, Flav = Flavonoids, Phe =Phenols,Vit C = Vitamin C, Vit E = Vitamin E, WE = Water Extract, ME = Methanol Extract, CE = Chloroform Extract, AE = Acetone Extract, GT = Gallotannins, += Significant, ++=Moderate, +++ = Verygood, - = Absent

Phytochemistry: Preliminary phytochemical studies of tubers of *Euphorbia fusiformis* using qualitative tests for various functional groups reveals the presence of flavonoid, phenol, tannins, protein, carbohydrates saponins, phytosterol, triterpenoids, fixed oil, and fat. It also contains vitamin C, vitamin E, and minerals [3].

Chemical Constituents: The rhizome of *Euphorbia fusiformis* contains a diterpene lactone caudicifolin, a polyphenol Ellagic acid, Ellagic glycoside *i.e.* 3, 3'-di-O methylellagic acid, and Euphol. The oil mainly consists of sesquiterpenes, a small amount of monoterpenes, and aliphatic compounds [63].

Structure of Some Chemical Constituent:

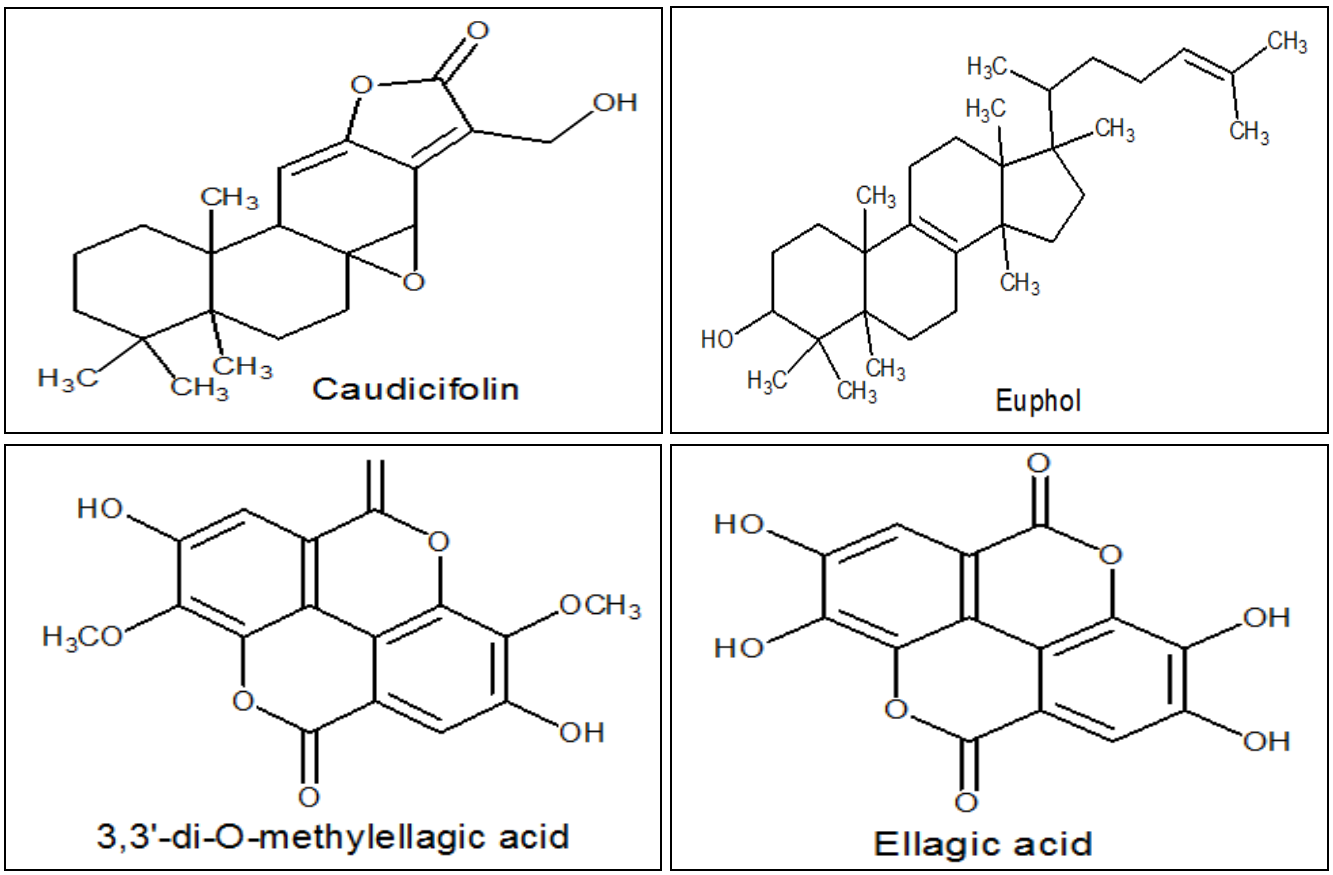


FIG. 3A: CHEMICAL CONSTITUENTS OF *EUPHORBIA FUSIFORMIS*

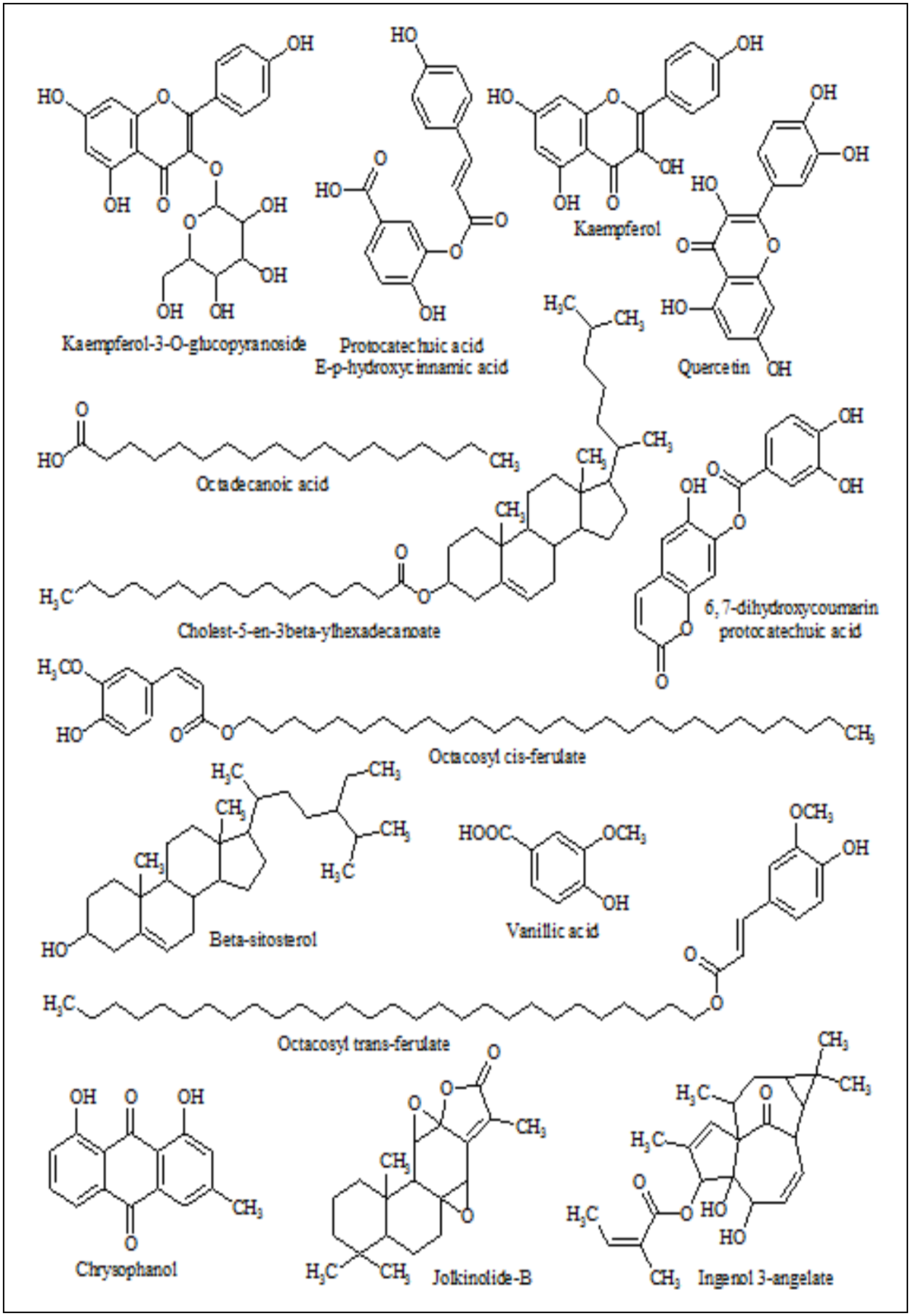


FIG. 3B: CHEMICAL CONSTITUENTS OF *EUPHORBIA* SPECIES

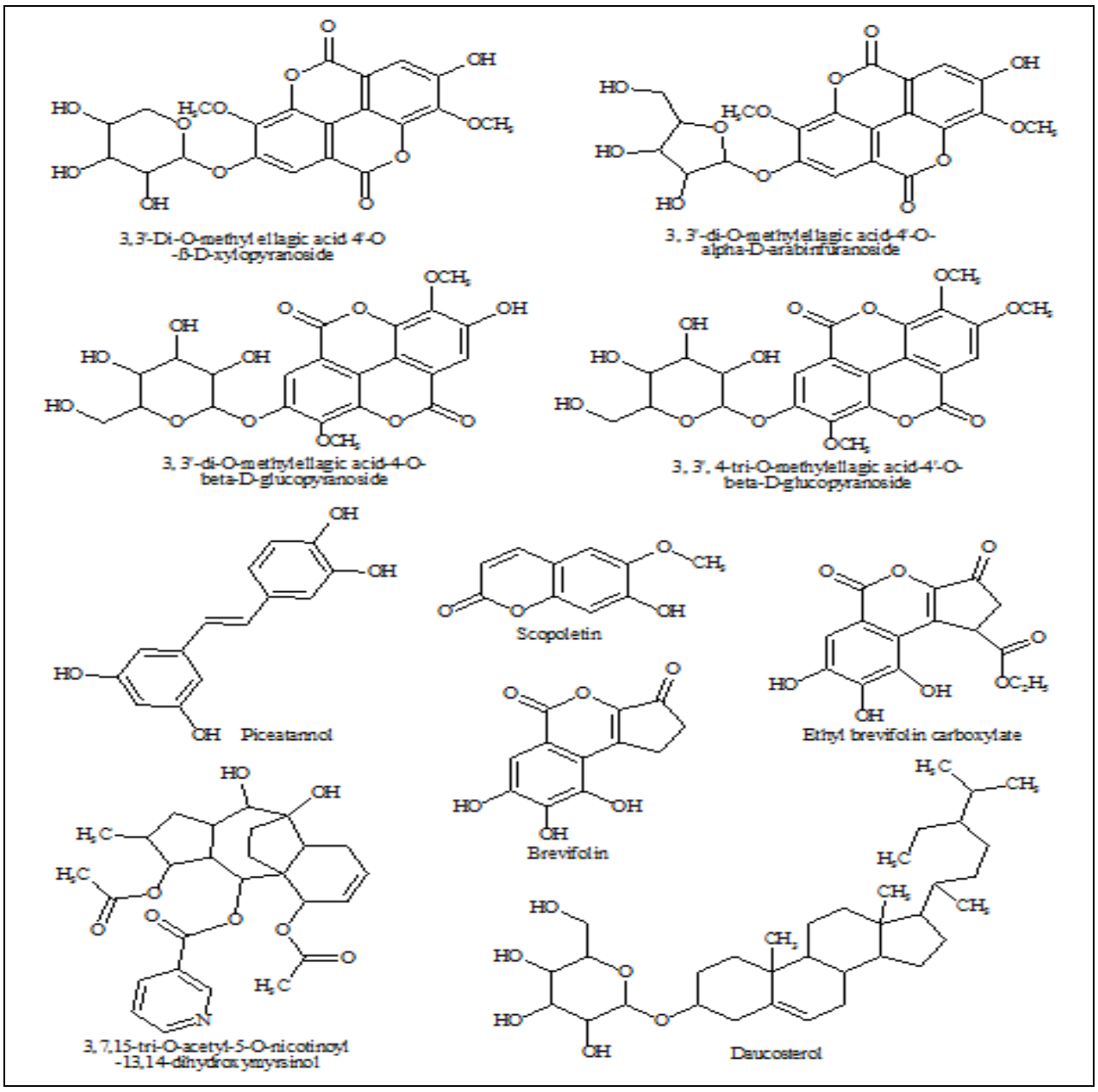


FIG. 3C: CHEMICAL CONSTITUENTS OF *EUPHORBIA* SPECIES

Pharmacology: Taken inspiration from the traditional uses of *Euphorbia fusiformis*, researchers have done scientific pharmacological screening. Various crude extracts of the plant and isolated compounds were evaluated for different biological activities by using a number of in vivo and in vitro models.

Antioxidant Activity: J kotesh kumar *et al.*, used DPPH radical scavenging method for screening of antioxidant activity of n-hexane extracts, ethyl acetate extracts of *Euphorbia fusiformis* and isolated compounds euphol, b-Sitosterol, caudicifolin, scoparone and scopoletin. Significant antioxidant activity was shown by the ethyl acetate extract (IC_{50} value 2.78 µg/ml), and moderate antioxidant activity was shown by its isolated compound Caudicifolin (IC_{50} value 3.25 µg/ml) Ascorbic acid was used as a standard (IC_{50} value 2.67 µg/ml) [2, 3, 12, 13, 14, 50].

Kamalanathan *et al.*, evaluated *E. fusiformis* leaf extracts for antioxidant activity using various assays like hydrogen peroxide radical, superoxide radical, DPPH radical, nitric oxide radical, and ferrous ion chelating potential. Extraction was carried out using various solvents like hexane, chloroform, acetone, ethyl acetate, and methanol. Remarkable antioxidant potential was observed for

DPPH radical scavenging activity in acetone extract with the least IC_{50} value of 15 µg/ml. IC_{50} value for hydrogen peroxide scavenging activity was found to be 42 µg/ml IC_{50} value. Maximum percentage of inhibition was demonstrated by methanolic extract fornitric oxide, superoxide and hydrogen peroxide radical scavenging activity. Acetone extract was found to be good in ferrous ion chelation properties (minimum IC_{50} value 62.86) [7].

Kavitha K.S evaluated Hydroxyl radical scavenging activity of *Euphorbia fusiformis* leaf and rhizome solvent extracts (chloroform, acetone, and ethanol). The standard antioxidants used were Butylated Hydroxy Anisole and Gallic Acid. The hydroxyl radical scavenging activities exhibited by all the extracts were found to be strong. The highest activity was shown by ethanolic extract of the leaf. It may be the active hydrogen donor ability of hydroxyl group of phenolic flavonoids present in ethanol extracts that is responsible for antioxidant activity [8, 9].

Sumit manna evaluated methanol and acetone extracts of *Euphorbia fusiformis* roots for antioxidant property by DPPH radical scavenging method. Highest radical scavenging was found with acetone extract of the plant because of more amounts of phenolic compounds [2].

Antifungal Activity: Antifungal activity was performed by using well-in-agar method for extracts of the rootstock and leaves of *Euphorbia fusiformis* plant using aqueous and organic solvents. The fungal strains used were *Candida albicans*, *Cryptococcus neoformans*, and *Aspergillus niger*.

Aqueous extracts showed no antifungal activity. Amongst organic extracts, ethanolic leaf extract and chloroform extracts showed a strong effect against *C. neoformans* and C. albicans, respectively, followed by other extracts. The combined extracts showed better activity against *C. albicans* as compared to *C. neoformans* [17-19].

Diuretic Activity: The diuretic activity was evaluated in rats. The root powder of *Euphorbia fusiformis* suspended in distilled water was administered orally. The volume of urine and its electrolyte concentrations were measured [20]. Concentration of excreted urinary Na +, K +, and Cl− was estimated by flame photometer, and the amount of chloride was determined titrimetrically.

The test drug produced 68.30% and 85.33% increase in the urine output at TED and TED × 02 dose levels, respectively, which is dose dependent and statistically significant. This indicates the diuretic activity of *E. fusiformis* root.

Anti-inflammatory Activity: It has been found that *E. fusiformis* n-Hexane extract has strong anti-inflammatory activity when screened in rats and mice using carrageenan-induced edema as acute inflammatory model and formaldehyde and adjuvant arthritis in rats as chronic arthritic model. Dose-related anti-inflammatory activity was observed after oral and intraperitoneal administration of the extract. When compared to the potency, *Euphorbia fusiformis* extract was found to be superior to PNB, a common non-steroidal anti-inflammatory drug [21].

Antibacterial Activity: Anti-bacterial properties of *Euphorbia fusiformis* were investigated using disc diffusion and well-in agar methods. Different types of gram-positive and gram-negative pathogenic strains were used. Aqueous and organic solvents were used for the extraction of the leaves and rootstocks. The rootstock extracts showed good anti-bacterial effect overleaf extracts. Methanolic extract demonstrated highest anti-bacterial activity followed by activity of extracts of acetone and chloroform. Ethanolic and aqueous extracts showed the least activity. A combination of aqueous and organic solvent (methanol, ethanol, and acetone) extracts of the tubers and leaves of *Euphorbia fusiformis* (1:1 ratio) were also tested for antibacterial activity. The combined antibacterial effects were evaluated using the disc diffusion method for selected gram-positive and gram-negative bacteria. Streptomycin anti-biotic was used as a positive control [4, 15]. Although the methanol and acetone extracts were observed as the most effective, a broad spectrum of antibacterial activity was shown by all extracts.

Hepatoprotective Activity: The hepatoprotective effect was observed against hepatic damage induced by rifampicin in rats. Significant effect was observed when ethanol extract of tubers of *Euphorbia fusiformis* was used.

The biochemical parameters used to measure the degree of protection were gamma-glutamyl trans-peptidase (GGTP), serum glutamate oxaloacetate transaminase (SGOT), serum glutamate pyruvate transaminase (SGPT), alkaline phosphatase (ALP), total bilirubin, and total protein. The control group given treatment with ethanolic extract significantly restored the increased levels of above parameters [26, 27].

Antinociceptive Activity: *Euphorbia fusiformis* root in the dried powder form was investigated for antinociceptive activity. Tail flick, paw licking model (formalin-induced, acetic acid writhing were the tests used for screening. No significant effect was observed on acetic acid-induced writhing upon oral administration of *Euphorbia fusiformis* powder. A significant rise in pain threshold was observed at both dose levels in the tail-flick test. However, at a high dose level, the formalin-induced paw licking responses were significantly inhibited at both phases. Central inhibitory mechanism was proposed to be involved in potent analgesic property of *Euphorbia fusiformis* root [28].

Galactagogue Activity: Galactagogue activity of ethanolic extract of *E. fusiformis* root was measured in pup and mother rats. A significant dose-dependent increase on milk secretion was measured indirectly by pup's body weight (or growth) in respect to untreated pups. The bodyweight of lactating mothers who remained unaltered indicated the galactagogue activity of plant [2].

In mother rats serum prolactin level, protein and glycogen concentrations in the tissues of the mammary gland was found to be increased as compared to control. Modulation of regulatory pathways of prolactin secretion may be the possible mechanism for augmentation of milk secretion and betterment of milk quality. The galactagogue efficacy of *E. fusiformis* can be supported by histological studies of mammary glands, which revealed the increase in the propagation of acini and lobuloalveolar size in the duct.

Action on Female Infertility: Lakshmana is a frequently mentioned drug in many ayurvedic literatures that is useful in enhancing fertility in females.

A preliminary experimental study gave enough pharmacological indications to identify *Euphorbia fusiformis* as the possible constituent of Lakshmana [29].

Infertile female obese rats were used for animal experiments. The reproductive parameters selected for the investigation were; a number of days taken for the vaginal opening, duration of estrus cycle, weights of reproductive organs like ovaries, uterus, and fallopian tubes length.

The histopathological analysis did not show any toxicological effect in experimental groups. The results revealed the importance of *Euphorbia fusiformis* plant for reversing infertility in animal models like obese rats.

Effect on Intestinal Transit Time: Screening of intestinal transit time was performed by using Swiss albino mice. Kaolin expulsion test was standardized before performing screening of intestinal transit time. The selected animals were divided into three groups.

The first 8 animal groups served as control. Second and third each of 6 animals group was administered with a test drug-using dose of 130 and 260 mg/kg, respectively. After one hour 40% kaolin solution was administered orally, and the beginning of kaolin expulsion was observed. Administration of *Euphorbia fusiformis* root powder significantly shortened the time required for expulsion of kaolin in dose-dependent manner. Thus it can be suggested that *Euphorbia fusiformis* increases intestinal motility [30].

Toxicity Studies: Acute oral toxicity studies were performed in mice. The ethanolic extract of E. *fusiformis* leaf and rhizomes, when administered orally in mice, Produce no mortality up to 10,000 mg/kg bw [13, 65]. Subchronic oral toxicity studies were performed in rats. No noticeable changes were observed in body weight, body temperature, normal behavior, and food intake at 125, 250, and 500 mg/kg bw oral dose. Also the ethanolic extract did not show any significant changes in hematological, biochemical and electrolyte parameter. Histological profile of liver and kidney was also observed to be unchanged [26].

In toxicity studies performed by Sumit manna *et al.*, oral administration of ethanolic extract of *E. fusiformis* was done in wistar rats. The dosing was done in graded fashion, *i.e.*, lower to higher doses (100 to 2000 mg/kg), and rats were observed for 3 consecutive days. The short-term analysis in rats showed no signs and symptoms of mortality or morbidity up to the dose of 2000 mg/kg[2].

Interspecific Covariance Analysis: Interspecific covariance analysis of *Euphorbia fusiformis* with its co-existed plants was done using Pearson's correlation coefficient. Multiple species case mode was used for analysis. Detailed habitat and analysis of community structure were taken into consideration [1].

The co-existence of *Euphorbia fusiformis* was observed with 20 flowering plants which are scattered into about 15 families and 20 genera. It indicates high diversity in taxonomy. The plant grows prominently in tropical deciduous forests with moderately undulated topography.

The species of *B. lanzan*, *P. acaulis*, *P. indica*, *M. latifolia*, and *H. indicus* show strong positive covariance with *E. fusiformis* and will assist in increasing the population of *E. fusiformis* during ex-situ or in-situ conservation of this rare taxa.

Phenology: Molecular studies were based on the position of the sequence of the given plant in the phylogenetic tree. Use of ribulose-15- bisphosphate carboxylase large subunit (rbcl) gene sequence has been done to determine molecular phylogeny of *Euphorbia fusiformis*. Its molecular phylogenetic relationships with other species showed the closest similarity with *E. abyssinica* [68].

Studies on Plant Regeneration: Somatic embryogenesis was derived from leaf explants. MS medium used for plantlet regeneration studies constituted 2, 4- Dichloro Phenoxy acetic acid (2, 4- D) 2.0 mg/L and α- Naphthalene Acetic Acid (NAA) 2.0 mg/L [62, 69, 70].

A higher percentage of somatic embryo formation was found at 2.0 mg/L NAA in leaf explants. An increase in a concentration above 2.0 mg/L of 2, 4-D/NAA, causes a reduction in somatic embryo formation, probably because of altered hormonal levels which are critical for embryo formation.

Mature leaf explants develop the calli-containing globular embryos. They were transferred to maturation Murashige and Skoog (MS) medium rich with 2.0 mg/L 2, 4-D + 0.5 mg/L 6-Benzylaminopurine (BAP), respectively. Each embryos undergo each of their typical stages of development. In case, further germination of embryos was not detected after 6 weeks, Fresh MS medium having specific concentrations of BAP (0.5 – 5.0 mg/L) alone were used as a subculture for germination of somatic embryos induced from explants of leaf. The best concentration found among different concentrations used was MS + 3.0 mg / L BAP. It took6 weeks for the germination of the somatic embryo and formation of plantlet.

In another study for micropropagation of *Euphorbia fusiformis* Buch-Ham. Shoot tip explants were used. MS medium enriched with (0.5-3.0 mg/l) BAP, Kn and Thidizuron (TDZ) was used for culturing of explants. Single shoot induction (85% and 77%) showed a High percentage response on MS medium supplemented with Kn (2.0 mg/l) and BAP (2.5 mg/l), respectively. For multiple shoot induction, MS medium enriched with TDZ (2.5 mg/l) showed strong response. Indole-3-butyric acid (IBA) has been found to be more effective than indole-3-acetic acid(IAA) for root induction on a half-strength MS medium from *in-vitro* shoots. With the use of the MS media with 0.5 mg/l of BAP, enhanced shoot bud's formation can be achieved. *In-vitro* roots were successfully induced by the use of 2.0 mg/l of IBA. Of Rooted plants can be effectively adapted by using the potting mix constituted with 80% sand admixed with 20% farmyard manure (v/v)

Conclusion and Future Perspective: This review compiles the comprehensive updated information of *E. fusiformis*, including its botanical description, geographical distribution, morphology, microscopy, ethnobotany, analytical studies, phytochemistry, pharmacology, toxicity studies, inter-specific covariance analysis, phenology, and plant regeneration studies. The current review reveals that, *E. fusiformis* was found to be having anti-inflammatory, analgesic, diuretic, antimicrobial, hepatoprotective, antioxidant, antifungal, anti-nociceptive, anticandidial, anticryptococcal and galactagogue activities. Caudicifolin, ellagic acid,

3, 3'-di-O methylellagic acid, and euphol have been reported as major phytoconstituents of the plant. It was also observed that there is no patent so far on this plant. The comprehensive information from the review will be helpful for researchers to focus on the preferential research areas yet to be examined and also to identify new chemical components responsible for its stated traditional activities.

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