OPEN ACCESS
Scholars International Journal of Traditional and Complementary Medicine
Abbreviated Key Title: Sch Int J Tradit Complement Med
ISSN 2616-8634 (Print) |ISSN 2617-3891 (Online)
Scholars Middle East Publishers, Dubai, United Arab Emirates
Journal homepage: http://saudijournals.com/sijtcm/

Review Article

Musa paradisiaca Linn. – A Comprehensive Review

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| **Received:** 09.06.2019 | **Accepted:** 19.06.2019 | **Published:** 29.06.2019
DOI:10.21276/sijtcm.2019.2.4.1

Abstract

Musa paradisiaca Linn**.** is a popular Indian medicinal plant belonging to the Musaceae family. This plant commonly known as plantain or banana is highly eating nutritious fruit over the world. A wide range of phytochemical constituents have been isolated from this plant. It has long been used in traditional Ayurvedic Indian medicine for various diseases. This plant is pharmacologically studied for analgesic activity, antidepressant activity, adaptogenic activity, anticonvulsant activity, CNS depressant activity, antidiarrhoeal activity, antiurolithiatic activity, antiulcerative activity, antimicrobial activity, antidiabetic activity, antioxidant activity, antilipidemic activity, antihypertensive activity, antiatherosclerotic activity, cytotoxic activity, Thrombolytic activity, Antimalarial activity, Antisnakevenom activity, Mutagenic activity, Hepatoprotective activity, Hair growth promoting activity, Wound healing activity, Bioabsorptive activity and Tablet disintegrant activity and many other activities. A comprehensive account of the morphology, phytochemical constituents, traditional uses, and pharmacological activities reported are included in view of the many recent findings of importance on this plant.

Keywords: *Musa paradisiaca* Linn, antidepressant activity, banana, Kadli.

INTRODUCTION

Herbal medicines have been used by the mankind since time immermorial. Ayurveda, the oldest traditional system of India, reveals that ancient Indians had a rich knowledge of medicinal value of different plants. India has been endowed with a very rich flora owing to the extreme variations in climate and geographical conditions prevalent in the country. With the advent in science, many of the crude drugs used in traditional system have been investigated scientifically. *Musa paradisiaca* Linn**.**, known as *Kadali* in sanskrit is a highly valued medicinal plant widely used in Indian traditional system of medicine for curing various ailments [1]. In this review a comprehensive account of the morphology, phytochemical constituents, traditional uses, pharmacological activities and toxicity study are included in view of the many recent findings of importance on this plant.

Taxonomic Classification [2]

Kingdom	: *Plantae*
Subkingdom	: *Tracheobionta*
Superdivision	: *Spermatophyta*
Division	: *Magnoliophyta*
Class	: *Liliopsida*
Subclass	: *Zingiberidae*
Order	: *Zingiberales*
Family	: *Musaceae*
Genus	: *Musa* L.
Species	: *M. paradisiaca* L.

Synonyms [3]

Musa sapientum L., *M. paradisiaca* L. var *sapientum* (L) Kuntze, Plantain

Vernacular names [1]

Sanskrit	:Vana laxmi, Kadali, Rambha (unripe), Mochaka
English	: Plantain or Banana
Hindi	: Kela
Maharashtrian	: kela
Gujarati	: Keda
Sindhi	: Kewiro
Telugu	: Kadalamu, Ariti
Tamil	: Kadali
Malayali	: Vasha
Konkan	: Keli

Flowering and Fruiting time: Throughout the year

Parts Used: Fruit, leaves and stems

Taxonomic and Genomic Classification [4-6]

Carolus Linnaeus, initially, classified banana into two species based on the pattern of consumption: *Musa sapientum* for dessert and *Musa paradisiaca* for plantains. The classification is based on chromosome numbers and morphological characters which is widely accepted by most of the taxonomists. *Musa paradisiaca* is a hybrid clone of *Musa acuminata* and *Musa balbisiana*. Cultivated bananas may be classed under 6 groups, each designated by letters which indicate their ploidy and genomic composition with respect to the two parent species (A for *Musa acuminata* and B for *Musa balbisiana*). Thus, AA and AAA (*Musa sapientum*) are diploid and triploid varieties of *Musa acuminata*. AB, AAB (*Musa paradisiaca*) and ABB are diploid and triploid varieties of *Musa balbisiana*. Swennen (1990) in his account of morphotaxonomy of plantain in Aftrica and elsewhere avoided the use of the nomenclature *Musa paradisiaca* for plantain and use genotypic description AAB to represent the taxon.

Occurance and Distribution [7, 8]

It is a perennial herb growing 10-40 feet in height (look like tree) commonly found in the tropical and subtropical area. It occurs in all tropical areas native to India and Burma. In India, it is mostly found in Tamil Nadu, Andhra Pradesh, Bihar, Madhya Pradesh, West Bengal, Maharashtra, and Gujarat. It is also distributed in New Guinea, America, Australia and tropical Africa. Cultivation is limited to Florida, The Canary Islands, Egypt, Southern Japan, South Brazil.



Morphology

Habit: *Musa paradisiaca* is one of the tallest herbaceous plant (up to 9 m long) with thick rhizome, pseudostem fleshy, succulent formed by the imbricate leaf sheaths.

Leaves: Large, oblong, petioles long channeled, bright glossy green.

Inflorescence: Spadix

Flowers: Flowers on recurved large, spadix drooping, the lower flowers all female, the upper all male, clustered and enclosed in the axils of large, reddish-purple caduceus, boat-shaped spathes or bracts. Calyx spathaceous, 5-toothed, white, corolla oblong, truncate, toothed, convolute round the stamens and style. Stamens 5 perfect and 1 small rudimentary or 0, filaments long stout, anthers linear, 2-celled. Ovary inferior, 3-celled, style long, stigma lobulate.

Fruit: Berry, fleshy, narrow at both ends, seeds rarely present in cultivated variety. Outer region of fresh fruits are greenish, shiny and mucilaginous; rough and black when dry and inner region white, hard, powdery with less or without seeds.

Microscopy

Flower [9-11]

Powder of flower of *M. paradisiaca* contains fibro-vascular tissues, groups of pigmented lignified cells containing starch grains, epidermal tissues with stoma, prism like calcium oxalate crystals, and spherical pollen grains. Pigmented and non pigmented sclerids, glandular trichomes, parenchyma of floral stalk and epidermal tissue with surface view are also present.

Bract reveals the presence of spiral vessels with phloem fibres, blackish-brown pigmented thick walled cells with spiral vessel and epidermal tissues with stomata, epidermal tissues with lateral view and epidermal cells with mesophyll tissues containing chloroplastid. fibro-vascular tissues, parenchymatous tissues, groups of sclerids, bundle of simple phloem fibres, calcium oxalate crystals, nonglandular trichomes and part of annual vessels along with group of xylem fibres are also present.

The adaxial epidermis of bracts of *M. paradisiaca* cultivars was glabrous and numerous paratetracytic, brachyparatetracytic and brachyparahexacytic-monopolar stomata. Rhaphide idioblast and inclusive bundle were absent from the adaxial epidermis of the bract as they seen in *M.*

sapientum. Papillae were absent from the abaxial epidermis in *M. paradisiaca* while it observe in *M. sapientum.*

Large and flattened fiber vascular tissues, small segment of pigmented sclereids, calcium oxalate crystal with prism-like structure were found in the powder stamen of *M. paradisiaca*.

The ovary of *M. paradisiaca* is trilocular containing two seeds in each locule. Ovary is covered with thick ovary wall, possessing multiple layer of outer cell.

Prism like calcium oxalate crystals, fragments of xylem fibres, groups of thick walled sclerenchyma and thick-walled parenchyma containing calcium oxalate crystals are reported in the transverse section of floral stalk. Powder also contains thick-walled parenchyma with simple trichome, Sieve tube with phloem parenchyma, fragments of sieve tubes, spiral vessels and thin walled pigmented sclerids.

Bark [10]

The transverse section of bark of *M. paradisiaca* showed that the epidermal cells are covered with cuticle. 2-3 hypodermal layers were found after epidermis. Different size groups of vascular bundle capped with sclerenchyma cell were observed.

Fruit [10]

Transverse section of unripe fruit of *M. paradisiaca* shows outer single layer epidermis made up of rectangle shaped parenchyma covered with thin cuticle papillae like outer protrution from each cell. Followed by epidermis, thick walled, irregular shaped, compactly arranged parenchymatous cells loaded with oval starch granules are present. Sclerenchymatous cells arranged in groups encircled with thin walled parenchymatous cells, tannin cells and vascular bundles scattered in this region. Presence of 10-14 layers of compactly arranged parenchymatous cells are arranged longitude way. Mesocarp showed loosely arranged, tangentially elongated parenchymatous cells with abundant oval starch grains, raphide bundles with needle shaped crystals and few longitudinally extended parenchymatous cells with tannin cells.

Powder study of fruit showed fragment of epidermal cells with papillae, different shape parenchymatous cells, Sclerenchymatous cells, reticulate helical vessels in groups, xylem cells in surface view, tannin cells, and abundant oval starch grains in groups.

Phytochemistry

Flower

Dopamine, dopa, noradrenalin, serotonin, caffeic, cinnamic, p-coumaric, ferulic, gallic and protocatechuic acids, campesterol, b-sitosterol, stigmasterol, cyclomusalenol, cyclomusalenone were reported in flower [12]. Datta *et al*., isolated a tetracyclic triterpene named (24R)-4α·-14α·, 24-trimethyl-5 α -cholesta-8, 25(27)-dien-3β-ol from the flowers [13]. Martin *et al.*, isolated a new hemiterpenoid glucoside named 1,1-dimethylallyl alcohol β-glucoside together with 3 known compounds, benzyl alcohol glucoside, syringin and (6S, 9R)-roseoside from flower buds of *Musa paradisiaca* [14]. Anthocyanins Cyanidin-3-rutinoside, 3-rutinoside derivatives (dephinidin, pelargonidin, peonidine and malvidin) and anthocynidins (delphinidin, cyanidin, petunidin, pelargonidin, peonidin and malvidin) as potential food colorants were isolated from banana bracts [15]. Phytochemicals studies on banana flower extracts showed the presence of alkaloids, glycosides, steroids, saponins, tannins, flavanoids and terpenoids [16]. Onyenekwe *et al.*, reported presence of tannins and glycosides in abundance while saponins, flavonoids, alkaloids, polyphenols and reducing sugars in moderate amounts in the aqueous stem extract [17]. Mishra *et al*., reported presence of alkaloids, carbohydrates, saponins, tannins, and phenols in aqueous and methanolic extracts of stamen. They also tested heavy metals (Zn, Cd, and Pb) and results showed that tested metals were in permissible limits [11].

Fruit

Catecholamines such as norepinephrine, serotonin, and dopamine were reported from peel and pulp of *M. paradisiaca* [18, 19]. Ketiku *et al*., determined the carbohydrate constituents and the amino acid make- up of green and ripe plantain. The quantity of total sugars considerably increased during ripening from 3.0 to 31.6% in the peel and from 1.3 to 17.3% in the pulp while starch concentration decreased from 50 to 35% and from 83 to 66% in the skin and the pulp, respectively. The skin was richer in cellulose (10%) and hemicellulose (13%) than the pulp which had 1.4% cellulose and 1.3% hemicellulose. The pulp protein was abundantly rich in arginine, aspartic acid and glutamic acid. Methionine was present in the lowest amount with tryptophan and cystine conspicuously being absent [20]. Singh and Sanwal separated three forms of α-glucan phosphorylase from mature banana fruit pulp by ammonium sulfate fractionation and DEAE-cellulose chromatography [21]. Ghoshal isolated two new acyl steryl glycosides, sitoindoside-III and sitoindoside-IV, and two new steryl glycosides, sitosterol gentiobioside and sitosterol *myo*-inosityl-β-D-glucoside, from peeled fruits of *M. paradisiaca* by gradient solvent extraction and extensive chromatography [22]. Lewis *et al.*, isolated flavonoids Leucocyanidin and synthetic derivative from the unripe pulp of plantain [23]. Mondal *et al.*, 2001 isolated water-soluble polysaccharides arabinose, xylose and galacturonic acid as major sugars, together with traces of galactose, rhamnose, mannose and glucose residues from mucilaginous exudates of *M. paradisiaca* [24]. Jang *et*

al., isolated a new bicyclic diarylheptanoid, rel-(3S,4aR,10bR)-8-hydroxy-3-(4-hydroxyphenyl)-9-methoxy-4a,5,6,10b-tetrahydro-3H-naphtho[2,1-b]pyran as well as four known compounds, 1,2-dihydro-1,2,3-trihydroxy-9-(4-methoxyphenyl)phenalene, hydroxyanigorufone, 2-(4-hydroxyphenyl)naphthalic anhydride and 1,7-bis(4-hydroxyphenyl)hepta-4(E),6(E)-dien-3-one, were isolated from an ethyl acetate-soluble fraction of the methanol extract of the fruits of Musa x paradisiaca cultivar [25].

Leaf

Baijal *et al*., studied the activities of starch phosphorylase, β-amylase, phosphohexoisomerase, acid and alkaline invertase, sucrose synthetase, sucrose phosphate synthetase and acid and alkaline phosphatase in various parts of the banana plant, using homogenates prepared in media supplemented with polyvinylpyrrolidone or Triton X-100. The results indicated that the supplement of choice depended on the enzyme and the tissue under study [26]. Shukla *et al*., reported variations in the activities of enzymes involved in carbohydrate metabolism between different parts of the banana plant (*Musa paradisiaca*). Sucrose synthetase is present in the highest concentration in rootstock and fruit pulp, and sucrose phosphate synthetase in the pseudostem. The highest ratio of the activity of sucrose phosphate synthetase to sucrose synthetase is found in leaves. Acid invertase is present in leaves, leaf-sheath and fruit pulp and is not demonstrable in rootstock and pseudostem. Neutral invertase activity is high in pseudostem and leaf-sheath. Starch phosphorylase is largely concentrated in fruit pulp and rootstock. The maximum activity of ATP:d-phosphoglucose pyrophosphorylase is found in rootstock. β-Amylase is not demonstrable in rootstock and is largely concentrated in leaf-sheath. Hexokinase is most active in rootstock and the lowest in leaves. Acid phosphatase and alkaline phosphatase activity is highest in fruit pulp and pseudostem. Glucosephosphate isomerase is most active in the rootstock and lowest in the leaves [27]. Kumar and Sanwal isolated two forms (A and B) of starch phosphorylase were found in the mature banana leaf by polyacrylamide gel electrophoresis and DEAE-cellulose chromatography. The young leaf contained only form A and the appearance of form B with leaf development was accompanied by a decrease in the content of form A. At a later stage of leaf maturity only form B could be found. The MWs of forms A and B were 450 000, and 220 000 respectively [28]. Cemaluk *et al*., reported higher protein content, fat, crude fibre and ash in the ground leaves than that in the peels. Higher carbohydrate and moisture were recorded in the peels than in the leaves [29].

Traditional Uses [1]

Root is anthelmintics, antibillious and a valuable alterative. Juice of tender root is used in haemorrhage. It is also used in anaemia and Cachexia. Root juice is used for urine retention, gonnorrhoea, bronchocele and strumous affections. Flowers are Astringent. Cooked flowers are used in diabetes. Juice of flowers mixed with curds used in dysmennorrhoea and Menorrhagia. Juice of stem is used in otalgia and haemoptysis. Ripe fruit is Laxative (fully ripe fruit taken in early mornings), emollient, demulcent and nutrient. Unripe fruit is cooling, astringent, and antiscorbutic (in dry state) and used in diabetes, diarrhea and dessert. Flour of green plaintain is used as chappatis in cases of dyspepsia with flatulence and acidity. Leaf is used as cool dressing to denuded wound and blisters.

Reported Pharmacological Activities

Analgesic activity

Hallikeri *et al.*, also reported antinociceptive activity of corm extract of *M. paradisiaca* cv Puttabale in acetic acid induced writhing test, tail-flick test and hot plate test [30]. Gupta *et al.*, reported that the aqueous extract of *M. paradisiaca* (250 mg/kg, 1000mg/kg, p.o.) showed significant analgesic activity in the experimental models (hot-plate method and writhing method) of rats [31].

Antidepressant Activity

Parle and Malik reported significant antidepressant potential of *Musa paradisiaca* fruit paste (5%, 10% and 20% w/w once daily for 15 successive days) in forced swim test and tail suspension test. Baclofen (10 mg/kg, i.p.), prazosin (62.5 mg/kg, i.p.) and p-CPA (100 mg/kg, i.p.) significantly antagonized this reduction in immobility time. Furthermore, *Musa paradisiaca* paste inhibited significantly the Monoamine oxidase and malondialdehyde levels. These findings reveal the anti-depressant potential of banana fruit appears to be related to anti-oxidant, pro-adrenergic, pro-serotonergic and/ or Monoamine oxidase inhibitory activity exhibited by the banana fruit [32]. Darji and Galani also reported significant reduction of the immobility time with 14 days treatment of hydroalcoholic extract of *Musa paradisiaca* fruit (250 and 500 mg/kg, p.o.) in the forced swim test and tail suspension test. Antidepressant potential of the fruit extract was reduced by Haloperidol (0.1 mg/kg, i.p.) and increased by Bromocriptine mesylate (2 mg/kg, i.p.). The neurochemical estimation revealed the level of norepinephrine, dopamine and serotonin were increased with 14 days fruit extract treatment [33].

Adaptogenic activity

Ittiyavirah and Anurenj studied antistress activity of acetone extracts of unripe fruit peels and ripe fruit peels acetone extracts of *M. paradisiaca* in stress induced depression, chronic variable stress and anoxia stress models of animal and result indicated significant antistress activity of unripe fruit peel extract in stress induced depress model while both extracts showed protective effect in other two models [34].

Anticonvulsant and CNS depressant activity

Hallikeri *et al*., reported that corm extract of *M. paradisiaca* cv. Puttabale containing total phenolics (628.6 µg/mg) and flavonoids (321.6 µg/mg) caused a significant reduction of Maximal electroshock induced convulsions, Pentylenetetrazole induced convulsions and locomotor activity. The extract also reduced the reaction time of forced swim test and muscle coordination test. The results suggest that the corm extract of *M. paradisiaca* cv. Puttabale possess anticonvulsant, and CNS depressant properties which may be attributable to the presence of phenolics and flavonoids in the plant [30].

Antidiarrhoeal Activity

Yakubu *et al*., reported antidiarrhoeal activity of sap of *M. paradisiaca* (0.25, 0.50, and 1.00ml) in the castor oil-induced diarrhoea, castor oil-induced enteropooling, and gastrointestinal motility models of rats. The sap significantly prolonged the onset time of diarrhoea, decreased the number, fresh weight, and water content of feaces, and increased the inhibition of defecations. The antidiarrhoeal activity of *Musa paradisiaca* sap attributed to the presence of alkaloids, phenolics, flavonoids, and/or saponins which may involve, among others, enhancing fluid and electrolyte absorption through *de novo* synthesis of the sodium potassium ATPase and/or reduced nitric oxide levels [35]. Arias *et al*., reported antidiarrhoeal activity of a solution containing 50 g/1 of plantain flour and 3. 5 g/l of sodium chloride in the clinical trial for the rehydration of children with acute diarrheal diseases [36]. In other clinical study reported by Emery *et al.*, banana flakes were found to be a cost effective treatment for diarrhea in enterlly fed patients when compared with routine medical care. The anti-diarrhoeal activity of banana may be due to the pectin content [37].

Antiurothiatic Activity

Panigrahi *et al.*, reported antiurolithiatic effect of aqueous-ethanol extract of *M. paradisiaca* pseudostem in ethylene glycol-induced nephrolithiasis in rats as evidenced by significant inhibition of Ethylene glycol (0.75%) and Ammonium Chloride (1%) induced rise in crystalluria and oxaluria, hypercalciuria, polyuria, crystal deposition in urine, raised serum urea, and creatinine as well as nitric oxide concentration and erythrocytic lipid peroxidation in lithiatic group [38]. Gopakumara reported antiurolithiatic activity of core of the pseudostem of *Musa Paradisiaca* in clinical study [39].

Antiulcerative Activity

Elango *et al*., studied antiulcer activity of a siddha drug-ripe fruit *Musa paradisiaca* bhasma in rats in which ethanol (80%) induced acute ulcer model and acetic acid induced chronic ulcer model. The bhasma was administered in the dose of 10 and 20 mg/kg orally 1 hour prior to ulcer induction in acute model and administered daily for period of 10 days in chronic model. The antiulcer activity of the bhasma was indicated by significant reduction of the ulcer index and rise in mucin content. Antioxidant activity was also observed by estimation of catalase, superoxidase dismutase, lipid peroxidation [40]. Herbert *et al*., investigated the cytoprotective effect of the methanolic extract of *Musa paradisiaca* in combination with catecholamines on indomethacin-induced peptic ulcer. The pylorus ligation technique was used for cytoprotective and Anti-secretory action of the extract. The results suggested that the methanolic extract of *Musa paradisiaca* possess cytoprotective effect against indomethacin-induced ulceration [41].

Antimicrobial Activity

Alisi *et al*., reported anti-microbial activity of aqueous extract of unripe fruit peels and leaves of *Musa paradisiaca* against *Staphylococcus* and *Pseudomonas* species in dehydrogenase assay. The fruit peel extract showed better activity against both bacteria than leaf extract, while the peel extract was more active against *Staphylococcus* (gram-positive) than *Pseudomonas* species (gram-negative) [42]. However, Ahmad and Beg reported that alcoholic extract of *Musa paradisiaca* stem showed no activity against Staphylococcus aureus, Salmonella paratyphi, Shigella dysenteriae, Escherichia coli, Bacillus subtilis, and Candida albicans [43]. Karadi *et al*., reported significant antimicrobial activity of methanolic extract of fruit peels of Musa paradisiaca against *Escherichia coli*, *Staphylococcus aureus*, *Bacillus subtilis*, *Pseudomonas aeruginosa* bacteria and *Candida albicans*, *Candida tropicalis*, *Aspergillus niger* fungi [44]. Jawla *et al.*, screened Ethanol and Ethanol:water (1:1) extracts of *M. paradisiaca* flowers for antibacterial and antifungal activity against standard strains of *B. subtilis*, *B. cereus*, *E. coli*, *K. pneumoniae*, *P. mirabilis*, *P. aeruginosa*, *S. pneumoniae*, *S. aureus*, *S. typhimurium* and *C. albicans*, *C. albidus* against amikacin and clotrimazole respectively. The EtOH and EtOH: water (1:1) extracts exhibited antimicrobial activity with minimum inhibitory concentrations ranging from 5.62–25.81 and 7.60–31.50 µg/mL respectively [45]. Karuppiah and Mustaffa evaluated antibacterial activity of hexane, ethyl acetate and methanol extracts of leaves of *Musa paradisiaca* and other musa species against multi-drug resistant pathogens causing nosocomial infection by agar well diffusion method. Ethyl acetate extracts of *Musa paradisiaca* showed highest activity against tested pathogens particularly *E. coli*, *P. aeruginosa* and *Citrobacter* sp. The minimum inhibitory concentrations were within the value of 15.63- 250 µg/mL and minimum bactericidal concentrations were ranging from 31.25- 250 µg/mL [46]. Okorondu *et al*., also reported the growth inhibition of *A pergillus. niger*, *A pergillus. oryzae* and *Rhizopus stolonifer* by *Musa paradisiaca* peel and stalk methanol and ethanol extract (1.0 mg/ml) [47]. Asuquo and Udobi evaluated for antibacterial potentials

of the ethanol extract of the leaf of *Musa paradisiaca* and its aqueous fraction against *S. aureus*, *Bacillus subtilis*, *P. aeruginosa*, *V. cholerae* and *S. dysenteriae*. The minimum inhibitory concentration of the aqueous fraction ranged from 3.125 to 25 mg/ml. The result showed that the aqueous fraction showed better antibacterial activity than ethanol extract [48]. Amutha and Selvakumari reported antibacterial activity of stem extract of *Musa* paradisiaca Linn. against Pseudomonas aeruginosa and Staphylococcus aureus with the zone of inhibition of Pseudomonas aeruginosa was 21 mm and Staphylococcus aureus was 19 mm at concentration of 500 µg/disc [49].

Antidiabetic Activity

Ojewole and Adewunmi reported significant hypoglycemic effect of methanolic extract of mature, green fruits of *Musa paradisiacal* (100-800 mg/kg p.o.) in normal and streptozotocin -treated, diabetic mice [50]. The Ethanol and Ethanol: water (1:1) extracts of *M. paradisiaca* flowers were administered to normal and alloxan induced diabetic rats. The blood glucose levels were measured daily after oral administration of extracts at doses of 100, 250 and 500 mg/(kg.d). Both the extracts reversed the permanent hyperglycemia within a week in alloxan induced diabetic rats. The EtOH extract (250 mg/kg) was found to be 7.69% more potent hypoglycemic effect than standard oral hypoglycemic drug, glibenclamide 0.2 mg/kg b.w., respectively [45]. Lakshmi *et al*., reported that the ethanolic extracts of all parts (leaves, fruit peels, stems and roots) and the hexane and chloroform fractions of leaves and fruit peels of *M. paradisiaca* showed promising antidiabetic activity in Streptozotocin induced diabetic rats [51]. Gheewala *et al.*, reported anti-diabetic activity of endophytic fungi which grows on flower of *Musa paradisiaca* [52]. Uhegbu *et al*., reported significant hypoglycemic effect of unripe *M. paradisiaca* supplemented diet (10, 20 and 30%) treatment for 21 days in alloxan induced-diabetic albino rats [53]. Bisht *et al*., evaluated *in-vitro* antidiabetic activity of methanol and hydroalcoholic extract taken from stem of *Musa paradisiaca was studied.* Results revealed that the extracts efficiently inhibit both alpha amylase and alpha glucosidase enzymes *in vitro* in a dose dependent manner [54].

Antioxidant Activity

The extracted flavanoids from *Musa paradisiaca* in rats found that the flavanoids from banana stimulated the activites of superoxide dismutase (SOD and catalase which might be responsible for the reduced level of peroxidation products such as hydroperoxides [55]. Shodehinde and Oboh evaluated and compared antioxidant activities of the aqueous extracts of unripe plantain products (raw, roasted, elastic pastry and boiled). (*Musa paradisiaca*), assess their inhibitory action on sodium nitroprusside induced lipid peroxidation in rat pancreas in vitro. The results revealed that all the aqueous extracts showed antioxidant activity and boiled flour had highest DPPH and OH radical scavenging activity while raw flour had highest Fe+2 chelating ability, sodium nitroprusside inhibitory effect and vitamin C content [56]. Ahmad *et al.*, measured the ability of the Musa paradisiacal tepal, flesh and skin extracts to scavenge free radicals using 2, 2-diphenyl-1- pcrylhydrazyl radical using quercetin as a reference radical scavenger Tepal methanol extract of was found to have the highest radical scavenging activity compared to others, such as tepal ethanol, tepal aqueous, skin methanol, flesh methanol and pure syringin. The IC 50 value of the tepal methanol extract was found to be 22.5 µg/ml. The highest total phenolic contents (expressed as microgram of Gallic acid equivalent per gram of the extracts) were found in tepal methanol extract (8000 µg/g) and the least in Flesh methanol extract (2150 µg/g) [57]. Uhegbu *et al.*, studied the effect of unripe M. *Paradisiaca* supplemented diet (10, 20 and 30%) treatment for 21 days in rat. The results showed antioxidant activity as evidenced by significant rise in superoxide dismutase, catalase, reduced glutathione and glutathione s-transferase level [53].

Antilipidemic Activity

Usha *et al*., studied effect of neutral detergent fiber from *Musa paradisiaca* on cholesterol metabolism. Rats fed neutral detergent fiber from unripe banana showed significantly lower levels of cholesterol and triglycerides in serum and tissues in both cholesterol diet and cholesterol free diet groups when compared to control rats fed fiber free diets. However, neutral detergent fiber from the ripe fruit had no such effect. Concentration of hepatic bile acids and fecal excretion of neutral sterols and bile acids were more in rats fed neutral detergent fiber from unripe banana in both groups. Absorption of glucose and cholesterol in rabbits was significantly lowered only in presence of neutral detergent fiber from unripe banana [58]. Vijayakumar *et al*., reported that oral administration of flavonoids extracted from unripe fruits of *Musa paradisiaca* showed significant hypolipidemic activities in male rats (Sprague Dawley strain) at a dose of 1 mg/100 g body weight/day. Concentrations of cholesterol, phospholipids, free fatty acids, and triglycerides showed significant decrease in the serum, liver, kidney, and brain of experimental animals. HMG CoA reductase activity was found to be enhanced, while activities of glucose-6-phosphate dehydrogenase and malate dehydrogenase were significantly reduced. Activities of lipoprotein lipase and plasma LCAT showed significant enhancement. A significant increase in the concentrations of hepatic and fecal bile acids and fecal neutral sterols was also observed indicating a higher rate of degradation of cholesterol. The present study indicates that although there is an increase in the rate of synthesis of cholesterol in the liver, the process of degradation exceeds the rate of synthesis [59]. Uhegbu *et al*., studied antilipidemic effect of *M.Paradisiaca*

supplemented diet (10, 20 and 30%) treatment for 21 days in rat. The result showed antilipidemic activity as evidence by reduction of total serum cholesterol and lipid peroxidation level [53].

Antihypertensive Activity

Osim *et al*., reported antihypertensive effect of ripe banana pulp (50 g/rat/day) in deoxycorticosterone enantate (DOC, 25 mg/rat) induced hypertensive rats. This effect may be due to the high tryptophan and carbohydrate content of banana that increases serotonin levels and gives serotonin-mediated natriorexic effect [60]. Orie reported that the effect of aqueous extract of plantain (*Musa paradisiaca*) showed concentration dependant hypotensive effect in both noradrenaline and potassium chloride-contracted aortic rings and portal vein isolated from rat [61].

Anriatherosclerotic Activity

Saraswathi and Gnanam reported that *M. paradisiaca* inhibits in vitro cholesterol crystallization. It has been reported that the peel extract of *Musa paradisiaca* in rats with diet-induced atherosclerosis showed anti-atherosclerotic effects, which may be due to the presence of dopamine, ascorbic acid and other anti-oxidants present in it [62]. Parmar and Kar tested the protective role of *Musa paradisiaca* peel extract (100 mg/kg) for 10 consecutive days in diet-induced atherosclerosis and thyroid dysfunction in rats. Wistar albino male rats were fed an atherogenic diet composed of 4% cholesterol, 1% cholic acid, and 0.5% 2-thiouracil (CCT) for 14 days to induce atherosclerosis. In rats fed the CCT diet alone, there was an increase in tissue lipid peroxidation, serum lipids, and glucose, with a parallel decrease in the levels of triiodothyronine and thyroxine, insulin, and high-density lipoprotein cholesterol. Abnormal histologic observations such as fatty liver with vacuolated hepatocytes, fatty cyst and nucleus pushed to periphery, and increased cardiomyocyte width and mild damage in renal tissues were seen in these rats. However, simultaneous treatment with *M. paradisiaca* extract ameliorated most of the biochemical and histopathologic alterations induced by the CCT diet, suggesting the protective role of these fruit peels against diet-induced atherosclerosis and thyroid dysfunction [63].

Cytotoxic and Thrombolytic Activity

Chowdhury *et al.*, reported significant cytotoxic and thrombolytic activity of methanol extract of *Musa paradisiacal* root *by* using brine shrimp lethality bioassay and *in vitro* clot lysis method respectively [64].

Anti-Malarial Activity

Bagavan *et al.*, reported that ethyl acetate and methanol extract of *Musa paradisiaca* flower showed antimalarial activity against chloroquine (CQ)-sensitive (3D7) and CQ-resistant (Dd2 and INDO) strains of Plasmodium falciparum in culture using the fluorescence-based SYBR Green assay [65]. Anbazhagan *et al.*, tested silver nanoparticles (AgNP) of *Musa paradisiaca* stem extract were against larvae and pupae of the malaria vector *Anopheles stephensi*, with LC_{50} of 3.642 (I), 5.497 (II), 8.561 (III), 13.477 (IV), and 17.898 ppm (pupae), respectively. Furthermore, the antiplasmodial activity of nanoparticles was evaluated against chloroquine-resistant (CQ-r) and chloroquine-sensitive (CQ-s) strains of *Plasmodium falciparum*, IC_{50} were 84.22 µg/ml (CQ-s) and 89.24 µg/ml (CQ-r), while chloroquine IC_{50} were 86 µg/ml (CQ-s) and 91 µg/ml (CQ-r) [66].

Antisnake Venom Activity

Borges *et al*., reported invitro inhibition of Phospholipase A2, myotoxic and hemorrhagic activities by *Musa paradisiaca* stem extract. Partial chemical characterization of MsE showed the presence of polyphenols and tannins and they are known to non-specifically inactivate proteins. MsE does not show protection against the toxic effects of snake venoms in vivo in mouse model [67].

Mutagenic Activity

Andrade *et al*., studied the mutagenic effect of *M. paradisiaca* fruit peel extract in mice assessed by the single gel electrophoresis (SCGE) and micronucleus assays. The result showed DNA damaging property in peripheral blood leukocytes for 1500 and 2000 mg/kg body weight [68].

Hepatoprotective Activity

Nirmala *et al*., investigated the hepatoprotective activity of alcoholic and aqueous stem extracts of Musa paradisiaca in CCl4 and paracetamol induced hepatotoxicity models in rats. Pretreatment with alcoholic extract (500 mg/kg), more significantly and to a lesser extent the alcoholic extract (250 mg/kg) and aqueous extract (500 mg/kg), reduced the elevated levels of the serum enzymes like serum glutamic-oxaloacetic transaminase (SGOT), serum glutamic pyruvic transaminase (SGPT), alkaline phosphatase (ALP) and bilirubin levels and alcoholic and aqueous extracts reversed the hepatic damage towards the normal [69].

Hair growth Promoting Activity

Savali *et al*., tested the effect of aqueous and methanolic extract of *M. paradisiaca* unripe fruits for hair growth promoting activity by studying hair length and microscopic study of follicles in vehicle control, 2% minoxidil treated and extract treated animals. Animals treated with aqueous and methanolic extract of *M. paradisiaca* showed better efficacy as compared to the control and standard group suggests that it has potential as a hair growth promoter [70].

Wound Healing Activity

Amutha and Selvakumari tested the methanolic extract of Musa paradisiaca Linn. stem on the burn wound created by using red hot steel rod from above the hind limb region of wistar albino rats and the progressive changes in healing were monitored every day. The wound contraction rate was observed based on the histopathological examination. It was concluded that the methanolic extract of Musa paradisiaca Linn. showed greater healing activity compared to control in Wistar albino rats [71].

Effect on Hormone Level

Parmar and Kar investigated effect of peel extracts from *Musa paradisiaca* on tissue lipid peroxidation and on the concentration of thyroid hormones, insulin, and glucose in male rats. In vitro inhibition of H(2)O(2)-induced lipid peroxidation in red blood cells of rats by 0.25, 0.50, 1.0, and 2.0 microg/mL of *M. paradisiaca* peel extract was observed in a dose-specific manner. Maximum inhibition was observed at 1.0 microg/mL. In the in vivo investigation, *M. paradisiaca* (100 mg/kg) was found to maximally inhibit hepatic lipid peroxidation. *M. paradisiaca* strongly inhibited the serum level of thyroid hormones for both T(3) and T(4) but increased the level of glucose [72].

Reproductive Activity

Alabi *et al*., studied the effects of administration of mature green fruits of *Musa paradisiaca* powder dissolve in distilled water (500 mg/kg, 1000 mg/kg) on the semen quality of adult male Wistar rats. Significant increment in the semen parameters was noticed in animals that received a lower dose of the plantain flour, but those animals who received the high dose had marked and very significant reduction in sperm cell concentration and percentage of morphologically normal spermatozoa [73]. Yakubu *et al.,* investigatsd the effect of oral administration of the aqueous extract of M. paradisiaca root on the testicular function parameters of male rat testes. The extract significantly increased ($p<0.05$) the testes-body weight ratio, total protein, sialic acid, glycogen, cholesterol, activities of alkaline phosphatase, γ-glutamyltransferase, acid phosphatase, and the concentration of testicular testosterone. In contrast, the extract decreased the concentrations of both luteinizing and follicle-stimulating hormones in the serum of the animals. The results revealed that oral administration of *M. paradisiaca* root extract at doses of 25, 50, and 100 mg/kg body weight enhanced the testosterone-dependent normal functioning of the testes [74].

Bioabosrptive Activity

Raw banana stalk (RBS), acid activated banana stalk (AABS) and base activated banana stalk (BABS) prepared by Ogunleye *et al.*, from banana stalk were used as biosorbents to remove Lead(II) from aqueous solution. The biosorbents were characterised using proximate analysis and Fourier transform infrared spectroscopy. Pb(II) of 1000 mg/L concentration was prepared from $Pb(NO_3)_2$ salt and other concentrations were obtained from this stock through serial dilution. Effects of adsorbent dose, temperature, initial metal concentration, contact time and pH on the percentage Pb(II) removal were evaluated. The Pb(II) concentrations in the solutions were analysed using Atomic Absorption Spectrophotometer. At an equilibrium time of 180 minutes, the percentage Pb(II) removal was 63.97%, 96.13% and 66.90% for RBS, AABS and BABS, respectively [75].

Tablet Disintegrant Activity

Singh *et al*., evaluated the three varieties of *Musa paradisiaca* L. in their unripe state as tablet disintegrant while formulating Orally Disintegrating Tablet (ODT) and other fast disintegrating dosage forms that showed promising results as potential tablet disintegrant for hardness, friability, *in vitro* disintegration time, wetting time and water absorption ratio [76].

Toxicity Study

Avirami *et al.*, evaluated toxicity profiles of pseudostem juice of *Musa paradisiaca* using acute oral toxicity and repeated dose 28-day oral toxicity as per OECD 425 and 407 respectively. During the entire period of study, behavioural changes, food intake, water intake and weekly body weight changes were evaluated. At the end of the treatment, serum samples were subjected to biochemical analysis. The data of the results obtained depicted that *Musa paradisiaca* L(pseudostem) juice administered at the dose level 2000 mg/kg for 28 days is very safe and has not produced any significant changes in both body weight changes and biochemical parameters [77].

CONCLUSION

Musa paradisiaca Linn. is widely distributed throughout various tropical regions. Fruit part of *Musa paradisiaca* Linn. is highly nutritious and most widely-consumed fruit throughout the world. The plants are characterized by the different characteristics in morphology and microscopy described here. The plant appears to have a broad spectrum of activity on several ailments. Various parts of the plant have been explored for Analgesic activity, antidepressant activity, adaptogenic activity, anticonvulsant activity, CNS depressant activity, antidiarrhoeal activity, antiurolithiatic activity, antiulcerative activity, antimicrobial activity, antidiabetic activity, antioxidant activity, antilipidemic activity, antihypertensive activity, antiatherosclerotic activity, cytotoxic activity, Thrombolytic activity, Antimalarial activity, Antisnakevenom activity, Mutagenic activity, Hepatoprotective activity, Hair growth promoting activity, Wound healing activity, Bioabsorptive activity and Tablet disintegrant activity and many other activities. It is reported to contain carbohydrates, proteins, flavonoids, sterol glycoside, vitamins,

minerals and catecholamines. With the availability of primary information, further studies can be carried out such as clinical evaluation, phyto-analytical studies, toxicity evaluation. The plant is pre-clinically evaluated to some extent; if these claims are scientifically and clinically evaluated then it can provide good remedies and help mankind in various ailments.

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