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The Chemistry, Pharmacological and Therapeutic Applications of *Asparagus racemosus*- A Review

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ABSTRACT

Medicinal plants are the nature's gift to human being to make disease free healthy life. It plays a vital role to preserve our health. India is one of the most medico-culturally diverse countries in the world where the medicinal plant sector is part of a time-honored tradition that is respected even today. Medicinal plants are believed to be much safer and proved elixir in the treatment of various ailments. In our country more than two thousand medicinal plants are recognized. *Asparagus racemosus* Willd. (Asparagaceae) is an important medicinal plant of tropical and subtropical India. Its medicinal usage has been reported in the Indian and British Pharmacopoeias and in traditional systems of medicine such as Ayurveda, Siddha and Unani. *A. racemosus* has been described as a rasayana herb and has been used extensively as an adaptogen to increase the non-specific resistance of organisms against a variety of stresses. Besides use in the treatment of diarrhoea and dysentery, the plant also has potent antioxidant immunostimuulant, anti-dyspepsia and antitussive effects. The present article includes the detailed exploration of pharmacological properties of *A. racemoses* is an attempt to provide a direction for further research.

KEY WORDS: *Asparagus racemosus*, Phytochemicals, Pharmacological action, Polyherbal formulation

INTRODUCTION

Plant and plant products are being used as a source of medicine since long. According to World Health Organization (WHO) more than 80% of the world's population, mostly in poor and less developed countries depend on traditional plant-based medicines for their primary healthcare needs (1). Medicinal plants are the nature's gift to human being to make disease free healthy life. It plays a vital role to preserve our health. India is one of the most medico-culturally diverse countries in the world where the medicinal plant sector is part of a time-honored tradition that is respected even today. Here, the main traditional systems of medicine include Ayurveda, Unani and Siddha. The earliest mention of the use of plants in medicine is found in the Rigveda, which was written between 4500 and 1600 BC. During British period due to Western culture our Traditional art of natural healing is disappeared. Now it is reappearing due to realization of its importance in curing diseases without any side effect.

Owing to the global trend towards improved 'quality of life', there is considerable evidence of an increase in demand for medicinal plant. (2). Use of plants for treating various ailments of both man and animal is as old practice as man himself. India is richly endowed with a wide variety of plants having medicinal value. These plants are widely used by all sections of the society whether directly as folk remedies or indirectly as pharmaceutical preparation of modern medicine. (3). In recent times, focus on plant research has increased all over the world and a large body of evidence has collected to show immense potential of medicinal plants used in various traditional systems (Ayurveda, Siddha and Unani) (4). Medicinal plants are a major source of biodynamic compounds of therapeutic values. (5)

Medicinal plants are assuming greater importance in the primary health care of individuals and communities in many developing countries. There has been an increase of demand in international trade because of very effective, cheaply available, supposedly have less or no side effects and used as alternative to allopathic medicines. Medicinal plants are believed to be much safer and proved elixir in the treatment of various ailments. (6).

Asparagus racemosus

Plant species

The genus Asparagus has been recently moved from the subfamily Asparagae in the family Liliaceae to a newly created family Asparagaceae. The Asparagus genus is considered to be of medicinal importance because of the presence of steroidal saponins and sapogenins in various parts of the plant (7). Asparagus is the Greek word for "stalk" or "shoot". About 300 species of Asparagus are known to occur in the world. Some of the European species to be mentioned are *A.officinalis, A. sprengeri and A. acutifolius* (8). Among the several species of 'Asparagus', *Asparagus racemosus, Asparagus gonaclades and Asparagus adsendens* grown in India and are most commonly used in indigenous medicine. (9). *Asparagus racemosus* is the one most commonly used in traditional medicine.

Scientific classification

Kingdom	:	Plantae
Division	:	Magnoliophyta
Class	:	Liliopsida
Order	:	Asparagales
Family	:	Asparagaceae
Genus	:	*Asparagus*
Botanical name	:	*Asparagus racemosus* Willd

Syn : Shatavari, Satavari, *Protasparagus racemosus*
Genus : *Asparagus*
Species : *racemosus*
Family : Liliaceae

Vernacular name

Asparagus racemosus Willd. is commonly called Satavari, Satawar or Satmuli in Hindi; Satavari in Sanskrit; Shatamuli in Bengali; Shatavari or Shatmuli in Marathi; Satawari in Gujarati; Toala-gaddalu or Pilli-gaddalu in Telegu; Shimaishadavari or Thanner Vittan Kizhangu or Inli-chedi in Tamil; Chatavali in Malayalam; Majjigegadde or Aheruballi in Kannada; Kairuwa in Kumaon; Narbodh or Satmooli in Madhya Pradesh; and Norkanto or Satawar in Rajasthan (10).

Taxonomy

The plant grows throughout the tropical and subtropical parts of India up to an altitude of 1500 m. The plant is a spinous under-shrub, with tuberous, short rootstock bearing numerous succulent tuberous roots (30–100 cm long and 1–2 cm thick) that are silvery white or ash coloured externally and white internally. These roots are the part that finds use in various medicinal preparations. The stem is woody, climbing, whitish grey or brown coloured with small spines. The plant flowers during February–March leaving a mild fragrance in it's surrounding and by the end of April, fruits can be seen with attractive red berries. Subshrubs hermaphroditic, Stems climbing, branched to 2m; branches usually distinctly striate-ridged, ridges ± cartilaginous denticulate. Cladodes in fascicles of 3-6(-8), linear, 1-2.5 cm x ca.1 mm, flat, midvein distinct. Leaf spur spinescent; spine straight or subrecurved, 1.5-2 cm on main stems, 5-10 mm on branches, woody, sharp. Inflorescences developing after cladodes, axillary, each a many-flowered raceme or panicle 1-4 cm; bracts ca. 1 mm. Pedicel 1.5-3 mm, slender, articulate at middle. Perianth campanulate, 2-3 mm. Stamens equal, ca. 0.7 mm; anthers yellow, minute. Fl. Nov.2n= 20*, 48 (10,12)

PHYTOCHEMISTRY

The major active constituents of *A. racemosus* are steroidal saponins (Shatavarins I–IV) that are present in the roots. Shatavarin IV is a glycoside of sarsasapogenin having two molecules of rhamnose and one molecule of glucose (Fig. 1). Other active compounds such as quercetin, rutin (2.5% dry basis) and hyperoside are found in the flowers and fruits; while diosgenin and quercetin-3 glucuronide are present in the leaves (10,11). A new steroidal saponin, shatavarin V (12), has been isolated from the roots of *A. racemosus*. Although this same structure has been attributed previously to a number of other saponins.

Asmari et al. (13) reported the presence of sarsasapogenin (Fig. 1) in natural plants of *A. racemosus* as well as in *invitro* cultures. Synthesis of sarsasapogenin in the callus cultures of *A. racemosus* was also reported earlier by Kar and Sen (14). DPPH (α,α -diphenyl-β-picrylhydrazyl) autography-directed separation resulted in the identification of a new antioxidant compound from *A. racemosus* named 'racemofuran' (15). Previously, the isolation and spectral data of a new isoflavone, 8-methoxy-5, 6,4'-trihydroxyisoflavone 7-*o*-β-D-glucopyranoside, was reported from the roots of the plant (16).

Sekine et al. (17) reported the isolation and characterization of a polycyclic alkaloid called 'Asparagamine' from *A. racemosus* that exhibited a unique cage-type structure and remarkable antioxitocin activity. Later, a new 9, 1-dihydrophenenthrene derivative named 'Racemosol' (Fig. 1) was isolated from the ethanol extract of roots (18). Its structure was elucidated by spectroscopic analysis as 9, 10-dihydro-1, 5-dimethoxy-8-methyl-2, 7-phenenthrenediol.

Also, sarsasapogenin and kaempferol have been isolated from the woody portion of tuberous roots of *A. racemosus*. These compounds were identified on the basis of chemical and spectroscopic evidence (19). Dinan et al. (20) conducted a survey on the seeds of 16 species of the genus *Asparagus* and found barely detectable levels of phytoecdysteroids in *A. racemosus*. Velavan and coworkers (21) reported the quantitative analysis of *A. racemosus* root extract revealed that the presence of flavonoids (36.7±3.9 mg/100ml), polyphenols (88.2±9.3 mg/100ml) and vitamin-C (42.4±5.1 mg/100ml).

Mishra *et al*. (110) shows that *Asparagus racemosus* root contains 4.6-to 6.1% protein; carbohydrates 36.8 to 47.5%; phenols 3.1 to 5.2mg/g; tannins 4.8 to5.1 mg/g; saponins 4.1 to % and ash 6.5 to 7.4%. Antioxidant activity is 20.4 to 23.9%. *Asparagus racemosus* root contain higher amount of phenolic compounds such as ferulic acid, rutin, quercetin, kaempferol and flavonoids.

Kamat *et al*. (44) reported that *Asparagus racemosus* root contain polysaccharide components (MW, 2000 kDa), rich in galactose, glucose and smaller amounts of arabinose. The relative percentage of monosaccharide is galactose, 54%; glucose, 28%; rhamnose, 4%; xylose, 5% and arabinose, 8%; others 1%.

Phytominerals

Choudhary (22) investigated the mineral content of *A. racemosus* using Atomic Absorption Spectrophotometer. The results are presented in the table 1. The minerals, which are biochemically important for the human system, are present in significant concentrations in different parts of *A. racemosus* playing important role in the enhancement of its medicinal property.

Medicinal value of Asparagus racemosus

Almost all parts of the plant are used by the Indian traditional system of medicine for the treatment of various ailments in human being. In particularly, the root of *A. racemosus* has significant medicinal properties.

Traditional Uses

Traditionally it is used as health tonic (23) and common Indian home remedy used as a rejuvenator, promoter of strength, breast milk and semen,(24) for cough, dyspepsia, edema, rheumatism, chronic fevers, (25) thirst, sunstroke,(26) and as an aphrodisiac, cooling tonic, antispasmodic, diarrhea and dysentery (25). This herb in Ayurvedic medicine used for female rejuvenation and female problems (27, 28), including: Amenorrhea, dysmenorrhea, endometriosis, infertility, leucorrhea, menopausal symptoms(28) (particularly mood swings and irritability), (29), menorrhagia, menstrual

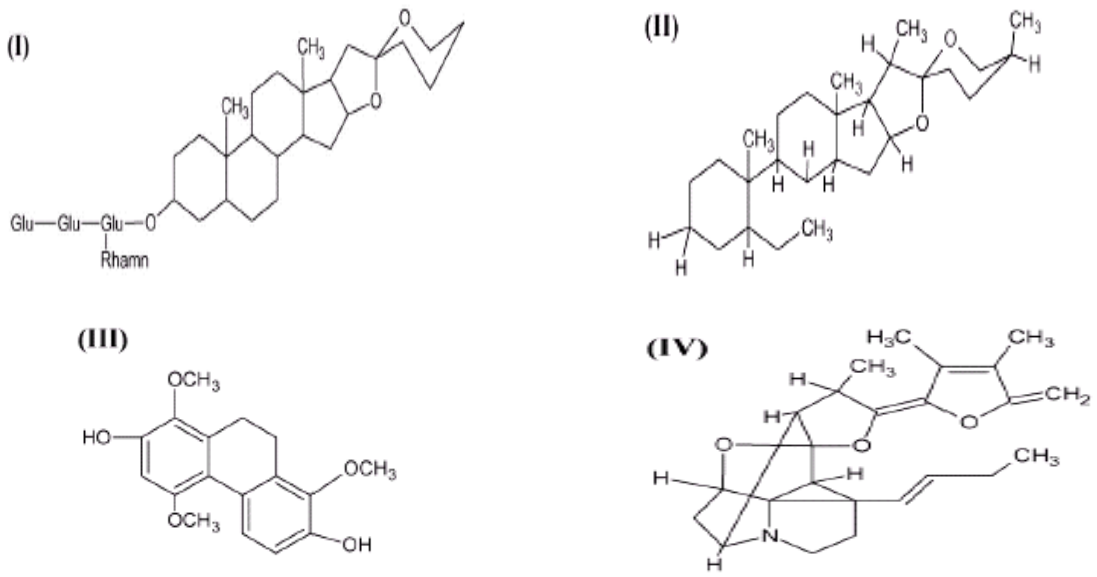

Fig. 1. Active principles of Asparagus racemosus
(I) Shatavarin, (II) Sarsasapogenin, (III) Racemosol and (IV) Asparagamine.

TABLE 1 : Mineral Contents of Asparagus Racemosus

Figures in Gram Per 100 Grams (Dry Plant Material)

Element	Root	Stem	Leaves	Twigs	Flowers	Seeds
Ca	0.192	0.115	0.115	0.417	0.424	0.022
Mg	0.100	0.043	1.300	0.430	0.340	0.050
K	2.06	1.64	1.29	3.47	4.79	1.78
Fe	0.004	0.002	0.010	0.004	0.007	0.003

Figures in Micro Gram Per Gram (Dry Plant Material)

Zn	39.17	30.04	64.95	36.38	117.97	30.39
Mn	9.73	5.50	48.29	21.82	28.14	6.41
Co	12.41	18.40	29.46	17.91	43.46	10.41

disorders, miscarriage or habitual abortion, pelvic inflammatory disease(28), and sexual debility. Other traditional uses: Arthritis, headache, toothache, stomachache(30) and peptic ulcers(31). Food uses: Roots are candied to provide a confectionary (25).

Root of *A. racemosus* has been referred as bitter-sweet, emollient, cooling, nervine tonic, constipating, galactogogue, aphrodisiac, diuretic, rejuvenating, carminative, stomachic, antiseptic (32) and as tonic. Beneficial effects of the root of *A. racemosus* are suggested in nervous disorders, dyspepsia, diarrhoea, dysentry, tumors, inflammations, cardiac debility, hyperdipsia, neuropathy, hepatopathy, cough, bronchitis, tumour, hyperacidity and certain infectious diseases (33). The decoction of root has been used in blood and eye diseases, cough, bronchitis and general debility (34). *A. racemosus* useful in leprosy, epilepsy, haemorrhoids, tuberculosis, nephropathy, ophthalmopathy, scalding of urine, and vitated condition of *vata* and *pitta* (35).

Rasayana property

A. racemosus Willd. (family Liliaceae) is a well-known Ayurvedic rasayana (36). The word 'Rasayana' literally means the path that 'Rasa' takes ('Rasa': plasma; Ayana: path). It is believed, in Ayurveda that the qualities of the 'Rasadhatu' influence the health of other dhatus (tissues) of the body. Hence any medicine that improves the quality of Rasa' ('Rasayana') should strengthen or promote the health of all tissues of the body. 'Rasayana' drugs act inside the human body by modulating the neuro-endocrino-immune systems and have been found to be a rich source of antioxidants (37). These Rasayana plants are said to possess the following properties: they prevent ageing, re-establish youth, strengthen life, brain power and prevent diseases (38,39), all of which imply that they increase the resistance of the body against any onslaught.

'Rasayana' is a specialized section of Ayurveda, which mainly deals with the preservation and promotion of health by

revitalizing the metabolism and enhancing immunity. Rasayana is a powerful antioxidants and are good hepatoprotective and immunomodulating agents. Rasayana therapy says that it arrests ageing ('Vayasthapam'), increase life span ('Ayushkaram'), intelligence ('Medha') and strength ('Bala') and thereby enable one to prevent disease (38). 'Rasayana' enhances the functions of the whole body system and haven been reported to treat generalized weakness (40).

Adaptogenic property

A. racemosus has also been reported to have potent adaptogenic activity (41). Adaptogens are substances, which enable to stand the stress and stain of life (Anti-stress) and give protection against infection and infirmity. The Russian scientist, Lazarev, coined the term 'adaptogen' in 1947 while working on a synthetic compound, dibazol (2 benzyl-benzimidazole) which was found to stimulate nonspecific resistance of organisms (42). Lazarev defined 'adaptogens' as agents, which allow an organism to counteract any adverse physical, chemical or biological stressor by generating non specific resistance and thus becoming 'adapted' to diverse demands imposed on it. Adaptogen is any substance that exerts effects on both sick and healthy individuals by 'correcting' any dysfunction(s) without producing unwanted side effects, was used as a point of departure. Adaptogens with those of medicinal agents that have activities as anti-oxidants, and/or anti- cancerogenic, immunomodulatory and hypocholesteroletic as well as hypoglycemic and choleretic action (43).

Nearly twenty years later the term 'adaptogen' was defined more precisely when Brekhman and Dardymov (42) put forth specific criteria that need to be fulfilled for a substance to qualify as an adaptogen. Thus, an adaptogen must

I. produce a nonspecific response, i.e. increase the power of resistance against multiple (physical, chemical or biological) stressors,
II. have a normalizing influence, irrespective of the direction of change from physiological norms caused by the stressor, and
III. be innocuous and not influence normal body functions more than required.

Action and uses in Ayurveda, Siddha and Unani:

Madhura rasam Madhura vipakam, seeta-veeryam; polyuria, chronic fevers, soma rogam, white discharge, internal heat, tonic. Hot, aphrodisiac, stomachic, tonic, gonorrhoea (25).

Toxicity

The LD_{50} is > 1g/kg. No toxic effects or mortality were observed with doses ranging form 50mg/kg to 1g/kg for four weeks. Acute and subacute (15-30 days administration) toxicity studies did not detect any changes in vital organ function tests (41).

Therapeutic Applications of *Asparagus racemosus*:

Antioxidant activity

Antioxidant activity of *A. racemosus* confirmed by Kamat *et al* (44) studies in rat liver mitochondria. An extracts from *A. racemosus* have been shown to exert potent antioxidant effects *invitro* against membrane damage induced by free radicals produced by gamma radiation in rat liver mitochondria. Both the crude extract as well as the purified aqueous fraction was found to inhibit lipid peroxidation and protein oxidation significantly which was comparable to that of the established antioxidants glutathione and ascorbic acid though the mechanisms responsible for the anti-oxidant properties.

The *invitro* antioxidant activity of aqueous extract of *A. racemosus* was investigated for activity of scavenging superoxide anion radicals, hydroxyl radical, nitric oxide radical, and hydrogen peroxide, metal chelation and reducing power. The extract was also studied for lipid peroxidation assay using young and aged rat brain mitochondria. The results of the present data show that the extract of *A. racemosus* root which contains highest amount of flavonoids, polyphenols and vitamin-C exhibits the greatest antioxidant activity through the scavenging of free radicals such as superoxide, hydroxyl radical, hydrogen peroxide and nitric oxide, which participate in various pathophysiology of diseases including ageing. *A. racemosus* root extract also exert iron chelating and reducing power activity. Overall, the plant extract is a source of natural antioxidants that can be important in disease prevention, health preservation and longevity promoter (21).

Anti-diarrhoeal effects

Diarrhoea has long been recognized as one of the most important health problems faced globally particularly by the population of developing countries. Each year diarrhoea is estimated to kill about 2.2 million people globally, a majority of whom are infants and children below the age of 5 years (45). Nanal et al. (46) found Satavari to be extremely effective in the treatment of *Atisar* (diarrhoea), *Pravahika* (dysentery) and *Pittaj shool* (gastritis) as described in Ayurvedic texts such as *Sushruta Samhita* and *Sharangdhar Samhita*. Ethanol and aqueous extracts of *A. racemosus* roots exhibited significant anti-diarrhoeal activity against castor oil induced diarrhoea in rats demonstrating an activity similar to loperamide (47).

The release of ricinoleic acid from castor oil results in inflammation and irritation of the intestinal mucosa causing the release of prostaglandins which stimulate motility and secretion. It is well known that 'prostaglandin E' causes diarrhoea in experimental animals and human beings. Therefore, the action of this extract can be attributed to the inhibition of prostaglandin biosynthesis, which in turn inhibits gastrointestinal motility and secretion. Since the *A. racemosus* root extract is composed of saponins, alkaloids, flavonoids, sterols and terpenes; further analysis is needed to identify the exact phytoconstituent(s) that imparts the anti-diarrhoeal action.

Antilithiatic effect

According to Christina et al (48) studies show that the ethanolic extract of *A. racemosus* was evaluated for its inhibitory potential on lithiasis (stone formation) induced by oral administration of 0.75% ethylene glycolated water to adult male albino Wistar rats for 28 days. The results of the study confirmed that this plant extract inhibits stone formation induced by ethylene glycol treatment and also confirmed by histopathological studies.

Antioxitocin

The alcoholic extract of the root exhibited antioxitocin activity. The saponin-glycoside at a doses of 20-50µg/ml produced a specific and competitive block of the pitocin syntocinon -induced contraction of rat, guinea pig and rabbit uteri in vitro as well as in situ. The saponin also blocked the spontaneous uterine motility. It was also found that the hypotensive action of syntocinon in cat was unaffected by previous administration of saponin (49).

Anticancer

The powdered root extract revealed inhibitory action on DMBA-induced mammary tumourigenesis in rats of Holtzman strain. The mammary tumour incidence showed a sharp decline when virgin female rats, normal or primed with 17 beta-estradiol treatment were put on diets containing 0.25 %0.5 %1 % or 2 % root extract powder for 10d prior to their exposure to DMBA. There was a increase in the latency period (50).

The *invitro* cytotoxicity of the plant was tested against Ehrlich ascites tumour cells in mice. The plant did not completely inhibit the tumour growth but possibly induced a lag in certain stages of its development (51). The crude alcoholic extract of the root 100 mg/kg administered orally to mice once daily for 17wk inhibited ochratoxin A OTA -induced suppression of chemotactic activity of murine macrophages obtained from mice as compared to controls receiving distilled water. There was also an increase in the interleukin-1 IL-1 and tumour necrosis factor TNF-α when compared to controls (52).

Anti-dyspepsia effects

A. racemosus also finds use in Ayurveda in the treatment of dyspepsia. The plant was found to have an effect comparable to a modern allopathic drug metoclopramide, which is a dopamine antagonist (53) used in dyspepsia to reduce gastric emptying time. In this study, 2 g-powdered roots of *A. racemosus* were compared to a standard treatment of metoclopramide (10 mg tablet) in eight normal healthy male volunteers, and the gastric emptying halftime was observed. There was no statistically significant difference between the actions of *A. racemosus* and metoclopramide. They hypothesized that Satavari might be a mild dopamine agonist. This isolated study merely supports the use of Satavari in traditional Ayurvedic medicine as an anti-Dyspeptic drug. It does not elaborate its mechanism of action, which can be an avenue for further research.

Antitussive effects

In yet another isolated report the methanol extract of *A. racemosus* roots showed significant antitussive activity on sulphur dioxide induced cough in mice with the cough inhibition being comparable to that of 10–20 mg/kg of codeine phosphate (54).

Antiulcer

Sairam et al. (55) studies show that the methanolic extract of fresh roots of *A. racemosus* showed significant protection against acute gastric ulcers induced by cold restraint stress, acetic acid, pylorus ligation, aspirin plus pylorus ligation, and cysteamine induced duodenal ulcers. In this study too it was concluded that the healing of gastric ulcers could be attributed to the effect of the *A. racemosus* extract on the mucosal defensive factors rather than the offensive ones. Also, the increase in the gastric emptying time aggravates duodenal ulcers and the ability of *A. racemosus* to limit this gastric emptying time may also be the reason for the duodenal anti-ulcer activity. Bhatnagar et al. (56) evaluated the anti-ulcer effect of *A. racemosus* on indomethacin-induced ulcers in rats. They found significant reduction in the ulcer index, free acidity, volume of gastric secretion and total acidity, which was comparable to the standard drug Ranitidine. In addition they an increase in the antioxidant defense.

The cytoprotective effect of the powders of dry fruits of Terminalia chebula and root of *A. racemosus* was studied on the experimentally induced acute gastric ulcerations. Duodenlal ulcers were produced by infusion of secretagogues and necrotising agents induced gastric lesions. A mixture of the two drugs in a dose of 1.5 g/kg each orally twice a day for 15 days was effective in preventing formation of duodenal ulcer and diminishing the ulcer index in gastric lesions (4).

Antiinflammatory activity

The methanolic extract of the root at doses of 20 and 400 mg/kg showed maximum inhibition of oedema of 18.6 % and 33.7 % at 3h with carrageenin and 22.2 % and 40.5 % at 5h with serotonin-induced rat paw oedema, respectively. The antiinflammatory activity of the extract was comparable to that of phenylbutazone (57). The decoction of the tuber when fed orally at a dose of 1.5 ml per 100 g, did not prevent the development of swelling of joints in experimental arthritis produced by formaldehyde injection in rats (58).

Hepatoprotecctive activity

Alcoholic extract of root of *A. racemosus* has been show to significantly reduce the enhanced levels of alanine transaminase, aspartate transaminase and alkaline phosphatase in CCl4-induced hepatic damage in rats, indicating antihepatotoxic potential of *A. racemosus* (59).

Antidiabetic

The dried ethanolic extract 250 mg per kg body weight and the inorganic parts 90 mg pure ash/kg bw of the root revealed hypoglycaemic activity in a single dose effect on the oral glucose tolerance test GTT in fasting albino rats (60). Govindarajan and coworkers have reported that antidiabetic activity of *A. racemosus*. Different doses of *A. racemosus* (100 and 250 mg/kg body weight) for 3 weeks significantly reversed antioxidant enzymes like SOD and CAT in liver and kidney in diabetic rats. It possesses moderate antidiabetic activity, but it exhibits potent antioxidant potential in diabetic conditions (61).

Insulin secretory activity

The ethanolic fraction of *Asparagus racemosus* stimulated the insulin secretion from isolated clonal β-cells. The constituents of *Asparagus racemosus* root extracts have wide ranging stimulatory effects of physiological insulinotopic pathway and as a source of active components may provide new opportunities for diabetes therapy (62)

Antiallergic activity

The alcoholic extract of the root at a dose of 50-mg/kg p.o. revealed antiallergic activity as evidenced by inhibition of passive cutaneous anaphylaxis in mouse by 57 % and in rat by 53 % (63).

Antimicrobial activity

Mandal et al (64) studies indicate that the different concentrations (50,100,150mcg/ml) of the methonal extract of the roots of *A. racemosus* showed considerable *invitro* antibacterial efficacy against *Escherichia coli, Shigella dysenteriae, Shigella flexneri, Vibrio cholerae, Solmonella typhimurium, Pseudomonas putida, Bacillus subtilis and Staphylococcus aureus*. The effects produced by the methonal extract were compared with chloramphenicol..

Antihelmintic activity

The aqueous extract of the root was lethal or inibitory, in *invitro* studies to hatching of *Meloidogyne javanica* and *M. arenaria*. A one % solution of the active material contained in the nematicide, Nemaphos O-O-diethyl-O-2-pyrazinyl phosphothionate suppressed hatching in dilutions up to 10,000 times and was comparable to the activity of 1ml undiluted plant extract 10 g/100 ml (65).

Anabolic action

The decoction of the root in a dose of 100 mg/kg bw for a varying period of 4 weeks to 8 months showed growth promoting effects in rats, indicating of its adaptogenic and anabolic activity (66).

Galactagogue

The effects of intramuscular administration (0.l ml (250 mg /kg)) of the crude alcoholic extract of the root were studied in post partum, estrogen-primed and non-primed rats. The extract increased the weight of mammary glands in post partum and estrogen-primed rats and the uterine weight in estrogen-primed group. The increase in the weight of adrenals coupled with the depletion of ascorbic acid suggested the release of pituitary ACTH. Estrogen- primed rats receiving the extract showed well-developed lobuloalveolar tissue with milk secretion. The mechanism of action of the extract may be through a direct action on the mammary gland or through the pituitary or pituitary adrenal axis due to the secretion of prolactin and ACTH (67).

Immunomodulators

The effect of the pretreatment of the decoction of the root 100 mg /kg/day for 15d orally: was evaluated against E. coli induced peritonitis in mice. The results indicated 50 % mortality at 16h as compared to 100 % in the control animals, thus suggesting an immunomodulating property (68). The immunotherapeutic modulation of intraperitoneal adhesions induced by caecal rubbing by the plant 200 mg/kg as total extrac administered orally for l5d in experimental rats was studied. The peritoneal macrophages obtained from normal rats exhibited 32 + 1.77 % phagocytosis while, those receiving the plant extract showed a significant increase in phagocytic activity 53 + 5.78 % of macrophages.

Pretreatment of animals with the plant extract in which surgery was used induce intraperitoneal adhesions and their sacrifice after 15d of surgery showed significant decrease in the adhesion scores. This was associated with a significant increase in the macrophage activity 70.1 + 2.52 % compared to that in surgical controls 53.77 + 10.8 %. Animals that received treatment following induction of adhesions also exhibited similar response. The peritoneal macrophages increased to 68.5 + 4.2 %. The findings provided a novel approach for the prevention and management of post operative adhesions (69).

The role of *A. racemosus* as an immunoadjuvant in traditional therapy is well documented and therefore it can be applied to evade the toxic side effects of synthetic chemotherapeutic drugs without compromising on its anti-tumour activity. Interestingly, in Ayurvedic medicine, AIDS is thought to be a disease of decreased 'ojas', defined as the essential energy of the body. Satavari is said to aid in the formation of 'ojas' and has been used in immune therapy (70). It is in situations like these that the function of *A. racemosus* as an immunoadjuvant can be scrutinized for use in adjuvant therapy in the management of HIV.

Estrogenic property

Estrogen replacement therapy is recommended primarily for the treatment of menopausal symptoms and for the prevention of cardiovascular disease and osteoporosis in postmenopausal women (71). At the same time, oestrogen therapy is known to increase the risk for endometrial cancer, breast cancer, venous thromboembolic events and gall bladder disease (72). Considering the threat associated with estrogen replacement therapy, Grady et al. (73) studied the relationship between hormone replacement therapy and the risk of endometrial cancer. They concluded that there is a substantial increase in risk associated with long periods of estrogen use and this risk persisted even several years after discontinuation of estrogen use.

Consequently, the interest in plant-derived estrogens or 'phytoestrogens' has increased due to the realization that hormone replacement therapy is neither as safe nor as effective as previously envisaged (74). Phytoestrogens are defined as any plant compound structurally and/or functionally similar to ovarian and placental estrogens and their active metabolites (75). Phytoestrogens affect the regulation of ovarian cycles and estrous in female mammals and the promotion of growth, differentiation and physiological functions of the female genital tract, pituitary, breast and several other organs and tissues in both sexes.

There are several studies that indicate a lower rate of breast cancer in populations with a high exposure to phytoestrogens (76-78). However, contradictory studies also exist regarding this evaluation. Studies conducted by Weinstein et al. (79) and Horn-Ross et al. (80) found no association between phytoestrogens and breast cancer. *A. racemosus* is well known for its phytoestrogenic properties and use as a hormone modulator (81).

The root extract of *A. racemosus* has also been traditionally used in Ayurveda to increase milk secretion during lactation. Sabnis et al. (82) found that the aqueous extract of *A. racemosus* roots increased the weight of mammary glands in post-partum and estrogen-primed rats and the uterine weight in the estrogen-primed group. This effect could be attributed to the action of released corticoids or prolactin. Oral administration of the alcoholic extract of *A. racemosus*

rhizome (30 mg/100 g body weight, daily for 15 days) to adult pregnant female albino rats had an estrogenic effect on the female mammary glands and genital organs

Effect on respiratory system

Higher doses of the alcoholic extract of root of *A. racemosus* re reported to cause dilatory effect on bronchial musculatur of guinea pigs bu failed to antogonise the histamin induced broncho-chonstriction. The extract has also been reported to produce depression of respiration in cat (83).

Effect on neurodegenerative disorders

In Alzheimer's and Parkinson's diseases, excitotoxicity and oxidative stress are the major mechanisms of neuronal cell death. Therefore, to combat neurodegenerative disorders, there is a need for a compound that can retard or reverse this neuronal damage. *A. racemosus* is a well-known nervine tonic in the Ayurvedic system of medicine. Parihar and Hemnani (84) conducted a study to investigate the potential of methanolic extract of *A. racemosus* roots against kainic acid (KA)- induced hippocampal and striatal neuronal damage in mice. Intra-hippocampal and intra-striatal injections of KA to anesthetized mice resulted in the production of excitotoxic lesions in the brain. After KA injection, impairment of hippocampus and striatal regions of brain was observed accompanied by increased lipid peroxidation, increased protein carbonyl content, decreased glutathione peroxidase (GPx) activity and reduced glutathione (GSH) content. GSH is an important antioxidant which acts as a nucleophilic scavenger of toxic compounds and as a substrate in the GPx-mediated destruction of hydroperoxides which would otherwise accumulate to toxic levels in brain tissues. The mice treated with *A. racemosus* extract showed an enhancement in GPx activity and GSH content, and reduction in membranal lipid peroxidation and protein carbonyl. They concluded that the plant extract plays the role of an antioxidant by attenuating free radical induced oxidative damage.

Hypolipidemic activity

A. racemosus has also been investigated for the reduction of cholesterol levels in hypercholesteremic rats by Visavadiya and Narasimhacharya (85). They found that *A. racemosus* root powder supplements decreased lipid peroxidation and caused a dose-dependent reduction in lipid profiles. The total lipids, total cholesterol and triglycerides in plasma and liver as well as plasma LDL (low-density lipoprotein) and VLDL (very low-density lipoprotein)-cholesterol decreased by more than 30%. Though it can be hypothesized that decreasing exogenous cholesterol absorption and increasing conversion of endogenous cholesterol to bile acid alleviate the hypercholesteremia; more research needs to be conducted to comprehend the mechanism of action responsible for this action.

Enzyme activity

Aqueous extracts of both fresh and dried root were found to have amylase and lipase activities, the activity being higher in the former. The optimum pH at which these activities could be found were 4 to 5 for ï¤¡-amylase, and 7.4 for lipase activity (86). The leaves of the seedling as well as the old plants possessed cholinesterase activity in vivo tests while the branch and roots were devoid of it (87).

Hormonal activity

Pure 9, 10-dihydrophenanthrene has been shown to interact with androgen receptors and may therefore inhibit androgen-dependent prostatic growth(88). *A. racemosuss*, the steroidal saponins, may be responsible for the hormonal like effect of *A. racemosus* and explain its traditional use as a reproductive tonic.

Cardiovascular effects

Alcoholic extract of the root of *A. racemosus* has been reported to produce positive ionotropic and chronotropic effect on frog's heart with lower doses and cardiac arrest with higher doses. The extract was found to produce hypotension in cats, which was blocked by atropine, indicating cholinergic mechanism of action. The extract also produced congestion and complete stasis of blood flow in mesentric vessels of mice and rat. Slight increase in the bleeding time and no effect on clotting time was observed on I. and V. day administration of the extract in rabbits (83).

CNS ACTIVITY

A preliminary study in rats to evaluate the central doparninergic effect of the plant, revealed that 1 g/kg and 2 g/kg of the powdered roots administered orally did not produce catalepsy or sedation (53).

Effect on Male Reproductive System

Interestingly, Satavari has also been studied for its influence on the male reproductive system by Ghumare et al. (89). They found that rats fed with *A. racemosus* root powder (0.5 g/kg rat feed) for 21 consecutive days exhibited significantly high testes weights as compared to untreated controls.This however, is an isolated report and can be investigated further to broaden our understanding regarding the effect of Satavari on the male reproductive system as well.

Miscellaneous

Velavan and Hazeena begum (90) evaluated the salubrious role of *A. racemosus* root extract (ARRE) on accumulation of oxidative damage products such Malondialdehyde (MDA),Protein carbonyls (PCO) , lysosomal marker enzymes acid phosphatase and Cathepsin D activity, aging marker lipofuscin and membrane bound H^+ ATPase activity in heart lysosome of aged rats. Results data revealed that ARRE has inhibiting effect on the accumulation of age-related oxidative damages and restored the enzyme activity and decreased the lipofuscin content in heart lysosomes. Thus, *A. racemosus* may be used as oxidative stress mediated diseases including aging.

Goel et al. (91) demonstrated teratogenicity in rats after the administration of methanolic extract of the plant. In light of this finding it would be desirable to carefully analyse the safety profiles of drugs developed from *A. racemosus*.

POLYHERBAL FORMULATION

A. racemosus root has been used as one of the ingredient in the preparation of various polyherbal formulations for medicinal use. The plant finds use in about 64 ayurvedic formulations which include traditional formulations such as 'Shatavari kalpa', 'Phalaghrita', 'Vishnu taila', etc. (Unnikrishnan, 1998). Abana® (containing 10 mg Satavari root

extract per tablet), Diabecon®(containing 20 mg Satavari root extract per tablet), EveCare®(containing 32 mg Satavari root extract per 5ml syrup), Geriforte®(containing 20 mg Satavari root powder per tablet), Himplasia®(containing 80 mg Satavari root powder per tablet), Lukol®(containing 40 mgSatavari root extract per tablet) and Menosan®(containing 110 mg Satavari root extract per tablet) are some formulations containing *A. racemosus* developed by Himalaya Herbal Healthcare, India .

Ricalex-Lactation

Joglekar et al. (92) observed an increase in milk secretion after administration of *A. racemosus* in the form of Ricalex® tablets (Aphali Pharmaceuticals; 40 mg concentrated root extract per tablet) to women suffering from deficient milk secretion. In another study, Sharma et al. (93) conducted randomized controlled trials to evaluate the effect of *A. racemosus* as a lactogogue in lactational inadequacy among women who had delivered at term without complications. Each 100 g dose of the medicine contained 15 g *A. racemosus* root extract. However, they found that a 4-week treatment with *A. racemosus* extract did not have any lactogogue effect.

EveCare- Menstrual disorders

EveCare® (containing 32 mg *A. racemosus* extract per 5ml syrup) is a herbal preparation formulated by the Himalaya Drug Co., Bangalore, to treat various menstrual disorders and threatened abortion. Administration of 'U-3107' in normal rats increased wet and dry uterine weights and also resulted in a marked increase in oestrogen levels with no change in progesterone levels as compared to control. The primary changes in uterine tissues are controlled by oestrogen and progesterone. The oestrogenic effect in this case was observed only in the presence of functional ovaries indicating that the formulation per se does not possess any oestrogenic activity. The effect is only evident in cases where the ovaries are functional. The rats from both controlled and treated group showed normal oestrous cycle (94).

In a study conducted by Nevrekar et al. (95), 'EveCare' capsules proved to be effective in the treatment of dysfunctional uterine bleeding (DUB). Seventy women in the age group found that by the end of the treatment, 63 women had achieved a regularized menstrual cycle. This action can be attributed to the local healing of the endometrium stimulated by endometrial microvascular thrombosis caused by high doses of phytoestrogens. In another study, a group of 40 patients suffering from dysmenorrhoea and pre-menstrual syndrome (PMS) were found to be symptom free after treatment with 'EveCare' (65). A drug prepared from *A. racemosus* (about 85 parts), patented by Dhaliwal (96) has been shown to be effective in the treatment of PMS in human females who experience adverse symptoms.

Menosan- Treatment for Post menopausal women

The energy source for the female reproductive system is oestrogen-dependent glycogen. Oestrogen increases the glycogen content in the uterus and any decrease in uterine glycogen would directly implicate oestrogen deficiency. Menosan® (containing 110 mg *A. racemosus* extract per tablet) is another polyherbal formulation that was found to cause an increase in uterine weight and uterine glycogen without altering serum oestrogen and progesterone levels in immature rats as against ovariectomized rats used as control (97). This study indicates that the phytoestrogen performs its function by binding directly to the oestrogen receptor without enhancing the endogenous oestrogen levels. Women undergoing menopause often experience a decline in the quality of life due to sleep deprivation, mood swings, lack of concentration, etc. 'Menosan' has also been studied for the treatment of post-menopausal symptoms (98). In a trial comprising 27 women in the age group of 35–56 years, significant relief from post-menopausal symptoms such as depression (90% relief), insomnia (83.33% relief), irritability (50% relief), weight gain (50% relief), bone and joint pains (40%), sweating (37.88%) and hot flashes (37.03%) was observed after the use of 'Menosan'. They concluded that since *A. racemosus* also has anti-bacterial activity in addition to it being a phytoestrogen; it is responsible for relief from symptoms like hot flashes and night sweats.

EuMil- Neurochemical modulator

'EuMil', a polyherbal formulation containing the standardized extracts of *Withania somnifera*, *Ocimum sanctum*, *A. racemosus* and *Emblica of.cinalis* was evaluated for its anti-stress activity in rats (99). Chronic electroshock stress for 14 days was found to increase the rat brain tribulin activity and decrease the monoamine neurotransmitter levels. 'EuMil' treatment normalized the perturbed nor-adrenalin, dopamine and 5-hydroxytryptamine concentrations and also attenuated the tribulin activity.

Mentat-Neurological disorder

'Mentat', a herbal psychotropic preparation containing *A. racemosus* has been found to be effective in the treatment of alcohol abstinence induced withdrawal symptoms such as tremors, convulsions, hallucinations and anxiety in ethanol administered rats (100) due to its anticonvulsant and anxiogenic action. However, it is unlikely that these are the only reasons for its de-addiction potential and therefore can be examined further.

Siotone-Adoptogenic activity

Bhattacharya et al. (101) undertook a study to investigate the adaptogenic activity of 'Siotone' (a herbal formulation consisting of *Withania somnifera*, *Ocimum sanctum*, *A. racemosus*, *Tribulus terristris* and shilajit) against chronic unpredictable, but mild, foot shock stress induced perturbations in behaviour (depression), glucose metabolism, suppressed male sexual behaviour, immunosuppression and cognitive dysfunction in albino rats. The stress indices for evaluation were gastric ulceration, adrenalgland and spleen weights, ascorbic acid and corticosterone concentrations of adrenal cortex and plasma corticosterone levels. Root powder of *Panax ginseng*, a reputed 'rasayana' herb was used as the standard adaptogenic agent for comparison purposes. The study suggested that 'Siotone' had significant ($p < 0.05$) adaptogenic activity in that it was able to reverse chronic stress-induced biochemical, physiological and behavioural perturbations and was qualitatively comparable to *Panax ginseng*.

Satavari mandur - Antiulcerogenic activity

Antiulcerogenic action of an ayurvedic herbo-mineral formulation 'Satavari mandur' (SM) was investigated for its efficacy in the treatment of cold restraint stress-induced gastric ulcer in rats (102). SM, the main ingredient of which is the root extract of *A. racemosus*, has been traditionally used in the treatment of peptic ulcers since the 19th century. It showed significant ($p < 0.05$) protection against pyloric ligation induced gastric ulcers due to the involvement of mucosal defensive factors (like mucous secretion) as against the involvement of offensive factors (such as acid and pepsin secretion) during the treatment of ulcers with the allopathic drug Ranitidine.

Abana- Cardioprotective

Increase in serum lipid levels especially cholesterol along with the generation of reactive oxygen species are the major reasons for the development of coronary artery disease and atherosclerosis. 'Abana', a herbo-mineral formulation containing 10 mg *A. racemosus* extract per tablet, was found to have significant hypocholesterolaemic effect in rats and therefore demonstrated a potential for use as a cardio-protective agent (103). They found that the total cholesterol, phospholipids and triglyceride levels were significantly lower (37–45%) as against the control. Since 'Abana' is a polyherbal formulation, further research needs to be conducted on the exact role that the *A. racemosus* component plays in the hypolipidaemic action.

GERIFORTE-AGING TONIC

Geriforte, a combination of several plants including *A. racemosus* and used as a restorative tonic in old age (104). Various workers have recently described the usefulness of Geriforte and its various properties. It is known to induce cellular regeneration, prevent arteriosclerosis, increase hormone utilization, enhance protein and carbohydrate metabolism and produce reduction in serum lipid (105,106). Besides, it has been proved useful clinically by producing a feeling of well being, increasing mental activity, lessening fatigue increasing appetite and sexual functions in the aging (107)

TRADE IN MEDICINAL PLANTS

The increasing global acceptance of complementary and alternative medicine has been the major reason for the steep rise in the demand for medicinal plants from countries like India, which are rich in biological diversity with 2 of the 14-megabiodiversity centers of the world located within its borders. In India, the per capita annual consumption of drugs is US$ 3, which is the lowest in the world since medicinal plants constitute the principal health care resource for the majority of the population (108). Therefore, for India, medicinal plants are a very important natural resource not only as their continued availability can assure health security for millions but also because it can be a potential to generate economic benefits. In terms of the volume and value of medicinal plants exported, India ranks second in the world, next only to China, which tops the list of exporting countries. Projections of global trade in medicinal plants indicate a steep upward trend for the future. According to the World Bank report of 1998, world trade in medicinal plants and related products is expected to touch US$ 5 trillion by AD 2050 (cited in Tewari, (108)). In India there is also a substantial volume of internal trade in medicinal plants, a large part of which is in the informal unorganized sector and hence it is virtually impossible to assess the current volume of trade in the domestic market.

Since the production base in *A. racemosus* relies mainly on the material collected from the wild, this species is increasingly under threat. Current harvesting practices are unsustainable and have resulted in depletion of the plant resource base. Pharmaceutical companies are also responsible to a great extent for inefficient, imperfect and opportunistic marketing of the plant resources. Since the prices paid to the gatherers, generally villagers, is low; commercial plant gatherers often 'mine' the plant resources rather than manage them, since their main objective is to generate a higher income. In *A. racemosus*, there is an almost 100% mark up in price from the collector level to the user (108). The demand for *A. racemosus* in 2001–2002 was 10,924.7 tonnes, which rose to 16,658.5 tonnes in 2004–2005 suggesting an annual growth rate of 15%. As a result, the raw material supply scenario is shaky, unsustainable and exploitative. It is due to these reasons that the National Medicinal Plants Board of India has identified 32 highly prioritized medicinal. Medicinal plants in urgent need for conservation to subvert the threat of extinction (109).

CONCLUSION

The therapeutic efficacy of *A. racemosus* extensively used in Indian System of Medicine has been established through modern testing and evaluation (pre-clinical and clinical trials) in different disease conditions. These studies place this indigenous drug a novel candidate for bioprospection and drug development for the treatment of such diseases as cancer, ulcer, diabetes, heart diseases, male and female infertility and postmenopausal syndrome. The medicinal applications of this plant, countless possibilities for investigation still remain in relatively newer areas of its function. Hence, phytochemicals and minerals of these plants will enable to exploit its therapeutic use.

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