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Review

Asparagus racemosus—Ethnopharmacological evaluation and conservation needs

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Abstract

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, Unani and Siddha.

Asparagus racemosus is mainly known for its phytoestrogenic properties. With an increasing realization that hormone replacement therapy with synthetic oestrogens is neither as safe nor as effective as previously envisaged, the interest in plant-derived oestrogens has increased tremendously making *Asparagus racemosus* particularly important. The plant has been shown to aid in the treatment of neurodegenerative disorders and in alcohol abstinence-induced withdrawal symptoms. In Ayurveda, *Asparagus 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, immunostimulant, anti-dyspepsia and antitussive effects.

Due to its multiple uses, the demand for *Asparagus racemosus* is constantly on the rise; however, the supply is rather erratic and inadequate. Destructive harvesting, combined with habitat destruction in the form of deforestation has aggravated the problem. The plant is now considered ‘endangered’ in its natural habitat. Therefore, the need for conservation of this plant is crucial.

This article aims to evaluate the biological activities, pharmacological applications and clinical studies of *Asparagus racemosus* in an attempt to provide a direction for further research.

Keeping in mind the fact that it is the active principle that imparts medicinal value to a plant; consistency in quality and quantity needs to be maintained to ensure uniform drug efficacy. Also, deliberate or inadvertent adulteration needs to be dealt with at an early stage. To overcome these prevalent problems, the availability of genetically superior and uniform planting material is essential. This can be obtained by a combination of various biotechnological tools involving chemoprofiling, tissue culture and use of molecular markers. Along with the application of these methods, proper agro-techniques and adequate marketing opportunities would encourage cultivation of *Asparagus racemosus* and thereby contribute to its conservation.

There are also several gaps in the existing literature with regard to the pharmacological actions of *Asparagus racemosus*. These include an incomplete understanding about the interaction/synergy between *Asparagus racemosus* and other plant constituents in polyherbal formulations; lack of information regarding the mode of action of the various constituents of *Asparagus racemosus*, etc. Consequently, we have suggested a ‘systems biology’ approach that includes metabolite profiling, metabolic fingerprinting, metabolite target analysis and metabonomics to enable further research.

Keywords: *Asparagus racemosus*; Conservation; Immunostimulant; Phytoestrogen; Shatavarin

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Contents

1. Introduction

The World Health Organization (2003) has estimated that 80% of the population of developing countries being unable to afford pharmaceutical drugs rely on traditional medicines, mainly plant based, to sustain their primary health care needs. India is one of the most medico-culturally diverse countries in the world where the medicinal plant sector is part of a time-honoured 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. It is however in Ayurveda that the specific properties of plants and their use as medicinal drugs has been dealt with in great detail. 'Ayurveda' literally translated means *science of life*. Ananthacharya (1939) in defining this system of medicine said *Ayurveda scrutinizes the subtle process of life, studies its nature, ways and conditions of development and deduces there-from a universal course of conduct for man's guidance in life*.

Ayurveda has eight divisions dealing with different aspects of the art of healing. These include *kaya cikitsa* (internal medicine), *salya tantra* (surgery), *salakya tantra* (treatment of diseases of the head and neck region), *agada tantra* (toxicology), *bhuta vidya* (management of mental ailments), *bala tantra* (pediatrics), *rasayana tantra* (rejuvenation therapy and geriatrics) and *vajikarana tantra* (science of aphrodisiacs). Around 1250 plants are presently used in various Ayurvedic formulations. *Asparagus racemosus* Willd. is one such important medicinal plant which is regarded as a 'rasayana' (plant drugs promoting general well being by increasing cellular vitality and resistance) in the Ayurvedic system of medicine (Goyal et al., 2003).

Asparagus racemosus is an important medicinal plant of tropical and subtropical India. Its medicinal usage has been reported in the Indian and British Pharmacopoeias and in indigenous systems of medicine. The genus *Asparagus* includes about 300 species around the world. The genus is considered to be medicinally important because of the presence of steroidal saponins and sapogenins in various parts of the plant. Out of the 22 species of *Asparagus* recorded in India; *Asparagus racemosus* is the one most commonly used in traditional medicine.

2. *Asparagus racemosus*: the plant species

Asparagus racemosus Willd. (family Asparagaceae; Liliaceae), 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 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 (Anonymous, Wealth of India, 1987).

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 its surrounding and

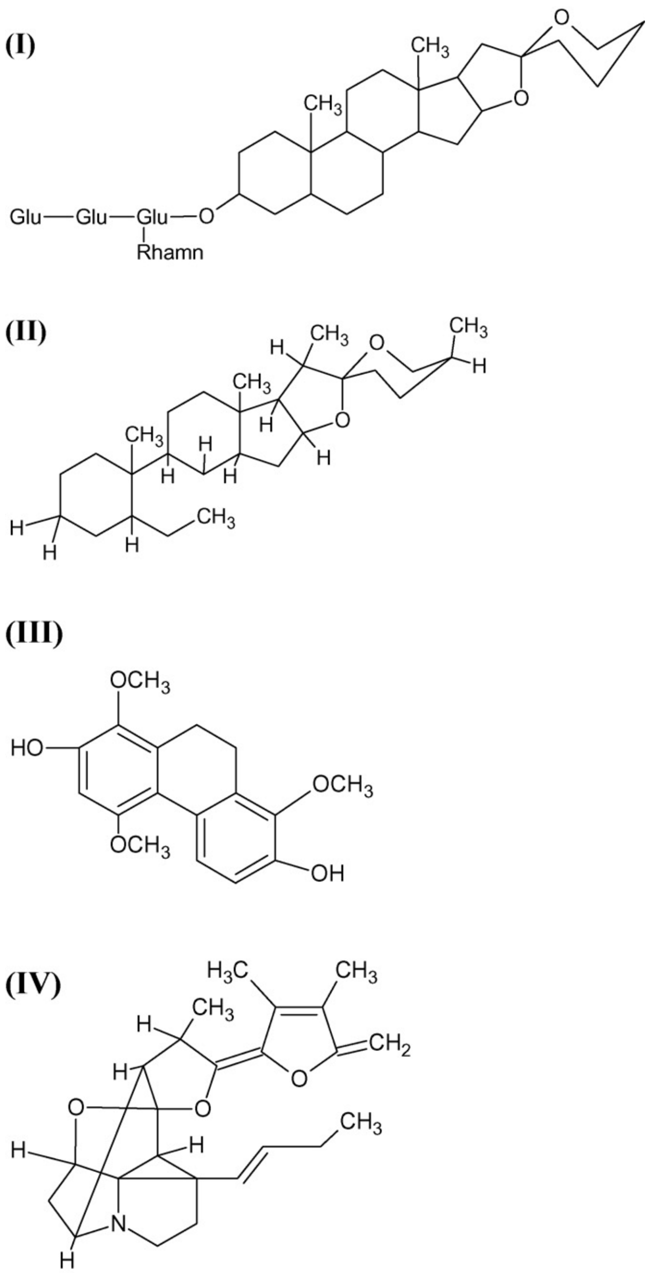

Fig. 1. Active principles of *Asparagus racemosus* (I) Shatavarin, (II) Sarsasapogenin, (III) Racemosol and (IV) Asparagamine.

by the end of April, fruits can be seen with attractive red berries (Anonymous, Wealth of India, 1987).

3. Active constituents of *Asparagus racemosus*

The major active constituents of *Asparagus 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 (Anonymous, Wealth of India, 1987; Thomsen, 2002).

Asmari et al. (2004) reported the presence of sarsasapogenin (Fig. 1) in natural plants of *Asparagus racemosus* as well as in *in vitro* cultures. Synthesis of sarsasapogenin in the callus cultures of *Asparagus racemosus* was also reported earlier by Kar and Sen (1985).

DPPH (α,α-diphenyl-β-picrylhydrazyl) autography-directed separation resulted in the identification of a new antioxidant compound from *Asparagus racemosus* named ‘racemofuran’ (Wiboonpun et al., 2004). 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 (Saxena and Chourasia, 2001).

Sekine et al. (1994) reported the isolation and characterization of a polycyclic alkaloid called ‘Asparagamine’ (Fig. 1) from *Asparagus racemosus* that exhibited a unique cage-type structure and remarkable anti-oxytocic activity. Later, a new 9, 1-dihydrophenenthrene derivative named ‘Racemosol’ (Fig. 1) was isolated from the ethanol extract of roots (Sekine et al., 1997). 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 *Asparagus racemosus*. These compounds were identified on the basis of chemical and spectroscopic evidence (Ahmad and Jain, 1991). Dinan et al. (2001) conducted a survey on the seeds of 16 species of the genus *Asparagus* and found barely detectable levels of phytoecdysteroids in *Asparagus racemosus*.

4. Pharmacological applications of *Asparagus racemosus*

Asparagus racemosus has been used in Ayurveda as a galactagogue, aphrodisiac, anodyne, diuretic, antispasmodic and nervine tonic since time immemorial (Sharma et al., 2000). 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 5 ml syrup), Geriforte®(containing 20 mg Satavari root powder per tablet), Himplasia®(containing 80 mg Satavari root powder per tablet), Lukol®(containing 40 mg Satavari root extract per tablet) and Menosan®(containing 110 mg Satavari root extract per tablet) are some formulations containing *Asparagus racemosus* developed by Himalaya Herbal Healthcare, India (Table 1).

4.1. Phytoestrogenic effects

Oestrogen replacement therapy is recommended primarily for the treatment of menopausal symptoms and for the prevention of cardiovascular disease and osteoporosis in postmenopausal women (Glazier, 2001). At the same time, oestrogen therapy is known to increase the risk for endometrial cancer, breast cancer, venous thromboembolic events and gall bladder disease (Barrett-Connor, 1998). Considering the threat associated with oestrogen replacement therapy, Grady et al. (1995)

Table 1
A summary of the studies conducted on the pharmacological activities of *Asparagus racemosus*

S. no.	Property/condition/	Model	Formulation/extract	Mode of action	Effect	Significance level	Reference
1.	Phytoestrogen						
	(a) Breast cancer	Rats (*in vivo*)	*Asparagus racemosus* root powder	Mammotropic and/or lactogenic influence rendering the mammary epithelium refractory to the carcinogen	Inhibitory	$p<0.05$	Rao (1981)
	(b) Lactogogue	Rats (*in vivo*)	Aqueous extract of *Asparagus racemosus*	Action of released corticoids or prolactin	Stimulatory	*	Sabnis et al. (1968)
		Pregnant rats (*in vivo*)	Alcoholic extract of *Asparagus racemosus* rhizome	*	Stimulatory	$p<0.001$	Pandey et al. (2005)
		Humans (*in vivo*)	*Asparagus racemosus* in form of Ricalex tablets (40 mg concentrated root extract per tablet)	*	Stimulatory	*	Joglekar et al. (1967)
		Humans (*in vivo*)	100 g medicine containing 15 g *Asparagus racemosus* root extract (polyherbal formulation)	*	No effect	*	Sharma et al. (1996)
	(c) Uterine weights	Rat uterus (*in vitro*)	Polyherbal formulation 'U-3107' or EveCare® (32 mg *Asparagus racemosus* per 5 ml syrup)	Increases the serum oestrogen levels but mechanism is unclear	Stimulatory	$p<0.05$	Mitra et al. (1999)
		Rats (*in vivo*)	Polyherbal formulation Menosan® (containing 110 mg *Asparagus racemosus* extract per tablet)	Phytoestrogen binds directly to the oestrogen receptor without enhancing the endogenous oestrogen levels	Stimulatory	$p<0.05$	Gopumadhavan et al. (2005)
	(d) Anti-oxytocin	Rat uterus (*in vitro*)	Saponin fraction of *Asparagus racemosus*	*	Inhibitory to oxytocin	*	Gaitonde and Jetmalani (1969)
		Rats (*in vivo*)	'U-3107'	*	Did not possess oxytocin activity	$p<0.05$	Mitra et al. (1999)
	(e) Dysfunctional uterine bleeding	Humans (*in vivo*)	EveCare®	Local healing of the endometrium stimulated by endometrial microvascular thrombosis	Inhibitory	*	Nevrekar et al. (2002)
	(f) Pre-menstrual syndrome	Humans (*in vivo*)	Polyherbal formulation with 85 parts *Asparagus racemosus*	*	Effective in treatment of symptoms	*	Dhaliwal (2003)
		Humans (*in vivo*)	EveCare®	*	Effective in treatment of symptoms with 80% relief observed	*	Swarup and Umadevi (1998)
	(g) Treatment of menopausal symptoms	Humans (*in vivo*)	Menosan®	Stimulation of immune response	Effective in treatment of symptoms	*	Singh and Kulkarni, 2002
	(h) Teratogenicity	Rats (*in vivo*)	Methanolic extract of *Asparagus racemosus* roots	*	*	$p<0.001$	Goel et al. (2006)
	(i) Testes weights	Rats (*in vivo*)	*Asparagus racemosus* root powder (0.5 g/kg rat feed)	Diameter of all germ cells except spermatids was found to increase	Stimulatory	$p<0.01$ to $p<0.001$	Ghumare et al., 2004

2.	Effect on neurological disorders						
	(a) Reversal of neuronal damage	Rats (*in vivo*)	Methanol extract of *Asparagus racemosus* roots	Antioxidant effect by attenuating free radical induced damage	Stimulatory	$p<0.05$	Parihar and Hemnani (2004)
	(b) Anti-stress	Rats (*in vivo*)	EuMil® (polyherbal formulation)	Normalization of augmented serotonergic function	Stimulatory	$p<0.05$	Bhattacharya et al. (2002)
	(c) Treatment of withdrawal symptoms	Rats (*in vivo*)	Mentat® (polyherbal formulation)	Anticonvulsant and anxiogenic action of *Asparagus racemosus*	Stimulatory	$p<5\%$	Kulkarni and Verma (1993)
3.	Anti-diarrhoeal action	Humans (*in vivo*)	0.5 mg *Asparagus racemosus* root powder in tablet form (four tablets; six times a day)	*	Stimulatory	*	Nanal et al. (1974)
		Rats (*in vivo*)	Ethanol and aqueous extracts of *Asparagus racemosus* roots	Inhibition of prostaglandin biosynthesis which in turn inhibits gastro-intestinal motility and secretion	Stimulatory	$p<0.05$	Venkatesan et al. (2005)
4.	Anti-dyspepsia action	Humans (*in vivo*)	2 g *Asparagus racemosus* root powder	*Asparagus racemosus* might be acting as a mild dopamine agonist	Stimulatory	$p<0.001$	Dalvi et al. (1990)
5.	Adaptogenic action	Rats (*in vivo*)	Aqueous extract of *Asparagus racemosus* roots	*	Stimulatory	*	Rege et al. (1999)
		Rats (*in vivo*)	Siotone® (polyherbal formulation)	Partly due to antioxidant activity	Stimulatory	$p<0.05$	Bhattacharya et al. (2004)
		Rats (*in vivo*)	EuMil® (polyherbal formulation)	Partly due to antioxidant activity	Stimulatory	$p<0.05$	Murugandam et al. (2002)
		Humans (*in vivo*)	Shatavari tablet	*	Stimulatory	*	Nanal et al. (1974)
6.	Anti-ulcerogenic action	Humans (*in vivo*)	12 g *Asparagus racemosus* root powder per day	Satavari heals ulcers by potentiating defensive factors and strengthening mucosal resistance	Stimulatory	$p<0.001$	Singh and Singh (1986)
		Rats (*in vivo*)	'Shatavari Mandur' (herbo-mineral formulation)	Involvement of mucosal defensive factors	Stimulatory	$p<0.05$	Datta et al. (2002)
		Rats (*in vivo*)	Methanolic extract of fresh roots of *Asparagus racemosus*	Involvement of mucosal defensive factors	Stimulatory	$p<0.05$ to $p<0.001$	Sairam et al. (2003)
		Rats (*in vivo*)	Methanolic extract of fresh roots of *Asparagus racemosus*	Increase in antioxidant defence	Stimulatory	*	Bhatnagar et al. (2005)
7.	Antioxidant action	Rat liver mitochondrion (*in vitro*)	Both crude and purified aqueous fraction	Unclear	Stimulatory	$p<0.001$	Kamat et al. (2000)
8.	Cardio-protection	Rats (*in vivo*)	Abana® (polyherbal formulation)	Maybe in part due to stimulation of the excretion of bile acids	Stimulatory in hypocholestero-laemic action	$p<0.001$	Khanna et al. (1991)
		Rats (*in vivo*)	*Asparagus racemosus* root powder supplements	Decreased cholesterol absorption and increased conversion of endogenous cholesterol to bile acid	Stimulatory in reducing cholesterol levels	$p<0.05$	Visavadiya and Narasimhacharya (2005)

Table 1 (*Continued*)

S. no.	Property/condition/	Model	Formulation/extract	Mode of action	Effect	Significance level	Reference
9.	Anti-bacterial action	Rats (*in vivo*)	Methanol extract of *Asparagus racemosus* roots	*	Stimulatory	*	Mandal et al. (2000a,b)
10.	Immunoadjuvant	Rats (*in vivo*)	Aqueous extract of *Asparagus racemosus* roots	Increase in antibody titres	Stimulatory	$p < 0.005$	Gautam et al. (2004)
		Rats (*in vivo*)	Methanol extract of *Asparagus racemosus* roots	Increase in white cell counts, haemoagglutinating and immunopharmacological actions	Stimulatory	$\alpha = 0.05$	Diwanay et al. (2004)
		Rats (*in vivo*)	Polyherbal formulation	'Maybe' due to an increase in secretory activities of macrophages	Stimulatory	$p < 0.05$	Rege et al. (1989)
		Rats (*in vivo*)	Polyherbal formulation	Inhibited carcinogen ochratoxin-induced suppression of chemotactic activity and production of interleukin-1 and TNF-α by macrophages	Stimulatory	$p < 0.05$	Thatte et al. (1987)
		Humans (*in vivo*)	*	*	Stimulatory in adjuvant therapy	*	Canadian AIDS Treatment Information Exchange (2005)
11.	Antitussive	Rats (*in vivo*)	*	*	Stimulatory	*	Mandal et al. (2000a,b)
12.	Styptic	Humans (*in vivo*)	Polyherbal formulation 'Styplon'	Main action 'appears' to be contraction of micro-circulation	Stimulatory	*	Tawde (1980)
13.	Geriatric tonic	Humans (*in vivo*)	Polyherbal formulation 'Geriforte' (20 mg *Asparagus racemosus* per 500 mg powder)	Arrests age related increase in activity of acid phosphatase in liver; stimulates cytochrome c oxidase level in the brain and in vitro uptake of testosterone by male reproductive organs	Stimulatory	$p = 0.05$	Saxena et al. (1983)

* Gaps in the table indicate absence of data from the cited literature.

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 oestrogen use and this risk persisted even several years after discontinuation of oestrogen use.

Consequently, the interest in plant-derived oestrogens or 'phytoestrogens' has increased due to the realization that hormone replacement therapy is neither as safe nor as effective as previously envisaged (Cornwell et al., 2004). Phytoestrogens are defined as any plant compound structurally and/or functionally similar to ovarian and placental oestrogens and their active metabolites (Whitten and Patisaul, 2001). Phytoestrogens affect the regulation of ovarian cycles and oestrous 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 (Beral, 2003; Dai et al., 2002; Buring et al., 1986). However, contradictory studies also exist regarding this evaluation. Studies conducted by Weinstein et al. (1993) and Horn-Ross et al. (2002) found no association between phytoestrogens and breast cancer.

Asparagus racemosus is well known for its phytoestrogenic properties and use as a hormone modulator (Mayo, 1998). Rao (1981) demonstrated the inhibitory action of *Asparagus racemosus* on DMBA-induced mammary carcinogenesis in rats. The root powder obtained after extraction with chloroform and methanol (1:1) was added in different percentages to the animal feed. Rats fed on a 2% *Asparagus racemosus* diet showed a significant ($p < 0.05$) decline in both tumour incidence and mean number of tumours per tumour bearing animal. They concluded that *Asparagus racemosus* root extract exerted a mammotropic and/or lactogenic influence on normal as well as on oestrogen-primed animals thereby rendering the mammary epithelium refractory to the carcinogen.

The root extract of *Asparagus racemosus* has also been traditionally used in Ayurveda to increase milk secretion during lactation. Sabnis et al. (1968) found that the aqueous extract of *Asparagus racemosus* roots increased the weight of mammary glands in post-partum and oestrogen-primed rats and the uterine weight in the oestrogen-primed group. This effect could be attributed to the action of released corticoids or prolactin. Oral administration of the alcoholic extract of *Asparagus racemosus* rhizome (30 mg/100 g body weight, daily for 15 days) to adult pregnant female albino rats had an oestrogenic effect on the female mammary glands and genital organs (Pandey et al., 2005).

Joglekar et al. (1967) observed an increase in milk secretion after administration of *Asparagus 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. (1996) conducted randomized controlled trials to evaluate the effect of *Asparagus 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 *Asparagus racemosus* root extract. However, they found that a 4-week treatment with *Asparagus racemosus* extract did not have any lactogogue effect.

'U-3107' or EveCare® (containing 32 mg *Asparagus racemosus* extract per 5 ml 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 (Mitra et al., 1999).

The saponin-rich fraction obtained from *Asparagus racemosus* was found to inhibit oxytocin induced uterine contractions *in vivo* (Gaitonde and Jetmalani, 1969). Mitra et al. (1999) also observed that 'U-3107' did not possess any oxytocin-like activity which may prove to be useful in conditions associated with hypermotility of the uterus as in dysmenorrhoea and threatened abortion.

In a study conducted by Nevrekar et al. (2002), 'EveCare' capsules proved to be effective in the treatment of dysfunctional uterine bleeding (DUB). Seventy women in the age group of 20–45 years with DUB were included in this study. They 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' (Swarup and Umadevi, 1998). A drug prepared from *Asparagus racemosus* (about 85 parts), patented by Dhaliwal (2003) has been shown to be effective in the treatment of PMS in human females who experience adverse symptoms.

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 *Asparagus 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 (Gopumadhavan et al., 2005). 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 (Singh and Kulkarni, 2002). 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 *Asparagus racemosus* also has anti-bacterial (refer section 4.7) activity in addition to it being a phytoestrogen; it is responsible for relief from symptoms like hot flashes and night sweats.

The flip side in the use of phytoestrogens is corroborated by a study conducted by Goel et al. (2006) which indicated certain teratogenic effects in rats after the administration of methanolic extract of *Asparagus racemosus* (ARM). In a prenatal study, they observed that ARM treatment caused swelling of legs, slow growth of foetal body and placental parts and an increase in the resorption of foetuses; while in the post-natal study, ARM treated groups exhibited a smaller litter of pups with increased mortality and delayed development. However, this study was unable to identify any specific constituent as being responsible for this teratogenicity and therefore needs to be investigated further.

Taking into account the existing literature on the subject, we can safely construe that although hormone replacement therapy is less effective in treating various menopausal symptoms and may actually increase the risk of cancer; the use of phytoestrogens derived from *Asparagus racemosus* cannot be blindly advocated due to the incomplete understanding and insufficient evidence regarding their potential health effects. It is also important to keep in mind that phytoestrogenic foods are different from phytoestrogenic herbs. While foods rich in phytoestrogens containing low amounts of the active compound (like soy bean, rye, oats, barley, etc.) can be consumed on a regular basis, phytoestrogenic herbs are usually extremely potent and not advisable for long term use and therefore the dosage and duration are extremely important. Clearly, more research is needed to define the effect of phytoestrogens from *Asparagus racemosus* and at the same time standardizing and characterising formulations and/or isolated phytoestrogens is imperative. In addition, developing an understanding of the effects of phytoestrogens from *Asparagus racemosus* as opposed to human oestrogens also holds great promise for further research.

Interestingly, Satavari has also been studied for its influence on the male reproductive system by Ghumare et al. (2004). They found that rats fed with *Asparagus 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.

4.2. *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. *Asparagus racemosus* is a well-known nervine tonic in the Ayurvedic system of medicine. Parihar and Hemnani (2004) conducted a study to investigate the potential of methanolic extract of *Asparagus 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 *Asparagus 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.

'EuMil', a polyherbal formulation containing the standardized extracts of *Withania somnifera*, *Ocimum sanctum*, *Asparagus racemosus* and *Emblica officinalis* was evaluated for its anti-stress activity in rats (Bhattacharya et al., 2002). 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', a herbal psychotropic preparation containing *Asparagus 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 (Kulkarni and Verma, 1993) 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.

Neurological and psychiatric disorders together account for more chronic suffering than all other disorders combined (Cowan and Kandel, 2001). Treating these problems however, remains a challenging field in medical science. Keeping in mind the encouraging leads and the limited data regarding the use of *Asparagus racemosus* in treating neurological disorders; more studies need to be conducted to fully exploit the potential of Satavari in this area.

4.3. *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 (WHO, 2005).

Nanal et al. (1974) 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 *Asparagus racemosus* roots exhibited significant anti-diarrhoeal activity against castor oil induced diarrhoea in rats demonstrating an activity similar to loperamide (Venkatesan et al., 2005). 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 *Asparagus 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.

4.4. Anti-dyspepsia effects

Asparagus 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 (Dalvi et al., 1990) used in dyspepsia to reduce gastric emptying time. In this study, 2 g powdered root of *Asparagus racemosus* was 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 *Asparagus 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.

4.5. Adaptogenic effects

As has been mentioned previously, *Asparagus racemosus* is described in Ayurveda as a 'rasayana' herb. 'Rasayana' is a group of plant drugs known to promote physical and mental health, improve defence mechanisms of the body and enhance longevity. In Ayurveda, the objectives of 'rasayanas' include *vayasthapana* (retarding ageing), *ayukaram* (enhancing lifespan), *medhabalakaram* (promoting intellect and physical strength) and *rogapaharanasamartha* (increasing resistance to diseases). These attributes are similar to the modern concept of 'adaptogens' which are the agents that increase the non-specific resistance of organisms against a variety of stresses (Dahanukar et al., 2000).

The prevention and management of stress disorders poses a major clinical challenge. Benzodiazepines (BDZs) appear to be effective only against acute stress and not chronic stress. Also, the prolonged use of BDZs exasperates physical dependence on it and increases the tolerance thereby limiting the utility of the medication. Under such circumstances, plant derived agents could induce an increase in non-specific resistance.

Rege et al. (1999) administered orally the aqueous, standardized extract of *Asparagus racemosus* to experimental animals, following which they were exposed to a variety of biological, physical and chemical stresses. Using a model of cisplatin induced alterations in gastrointestinal motility; the ability of this extract to exert a normalizing effect, irrespective of direction of pathological change was tested. *Asparagus racemosus* reversed the effects of cisplatin on gastric emptying, and also normalized cisplatin induced intestinal hypermotility. Bhattacharya et al. (2004) undertook a study to investigate the adaptogenic activity of 'Siotone' (a herbal formulation consisting of *Withania somnifera*, *Ocimum sanctum*, *Asparagus 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, adrenal gland 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*. Later, another polyherbal formulation, 'EuMil' was studied to examine adaptogenic and antistress activity against similar stresses as in the previous study (Murugandam et al., 2002). *Panax ginseng* was once again used for comparison. 'EuMil' too like 'Siotone', exhibited significant adaptogenic and antistress activity and was also able to reverse chronic stress-induced biochemical, physiological and behavioural perturbations comparable to *Panax ginseng*. In addition, acute and subacute toxicity studies showed that 'Siotone' and 'EuMil' both were devoid of any toxic effects. Both Siotone and EuMil had identical effects on similar types of stresses and since both formulations contain *Withania somnifera*, *Ocimum sanctum* and *Asparagus racemosus*, we can conclude that these three herbs may be performing the major function with respect to this particular action.

Nanal et al. (1974) studied the effect of *Asparagus racemosus* on *Amlapitta* (hyperacidity), *Grahani* (ulcerative colitis), *Parinam shool* (septic ulcer) and *Vataj shool* (spastic colon) and observed an amelioration of symptoms. 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 (Datta et al., 2002). SM, the main ingredient of which is the root extract of *Asparagus 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. In another study by Sairam et al. (2003), the methanolic extract of fresh roots of *Asparagus 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 *Asparagus 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

Asparagus racemosus to limit this gastric emptying time may also be the reason for the duodenal anti-ulcer activity. Bhatnagar et al. (2005) evaluated the anti-ulcer effect of *Asparagus racemosus* on indomethacin induced ulcers in rats. They found a 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 observed an increase in the antioxidant defence.

Previously, extracts from *Asparagus racemosus* have been shown to exert potent antioxidant effects *in vitro* against membrane damage induced by free radicals produced by gamma radiation in rat liver mitochondria (Kamat et al., 2000). 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 are still unclear.

4.6. Cardio protective effects

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 *Asparagus 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 (Khanna et al., 1991). 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 *Asparagus racemosus* component plays in the hypolipidaemic action.

Asparagus racemosus has also been investigated for the reduction of cholesterol levels in hypercholesteremic rats by Visavadiya and Narasimhacharya (2005). They found that *Asparagus 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 the hypercholesteremia is alleviated by decreasing exogenous cholesterol absorption and increasing conversion of endogenous cholesterol to bile acid; more research needs to be conducted to comprehend the mechanism of action responsible for this action.

4.7. Anti-bacterial effects

In an isolated study, different concentrations of the methanol extract of the roots of *Asparagus racemosus* have also shown considerable antibacterial efficacy under *in vitro* conditions against *Escherichia coli*, *Shigella dysenteriae*, *Shigella sonnei*, *Shigella flexneri*, *Vibrio cholerae*, *Salmonella typhi*, *Salmonella typhimurium*, *Pseudomonas putida*, *Bacillus subtilis* and *Staphylococcus aureus* (Mandal et al., 2000b). The antibacterial effect of *Asparagus racemosus* may also be playing a secondary role in its action with respect to other functions of the plant as well and therefore needs to be studied in greater detail.

4.8. Immunoadjuvant effects

The immunoadjuvant potential of *Asparagus racemosus* was studied in experimental animals immunized with diphtheria, tetanus, and pertussis (DTP) vaccine (Gautam et al., 2004). After challenge, animals treated daily with *Asparagus racemosus* aqueous root extract (100 mg/kg body weight) showed a significant increase ($p = 0.0052$) in antibody titres to *Bordetella pertussis* as against the untreated animals. Reduced mortality coupled with overall improved health status was observed in treated animals and this indicated the development of a protective immune response.

Extracts and formulations prepared from *Asparagus racemosus* exhibited various immunopharmacological actions such as increases in white cell counts, haemagglutinating and haemolytic antibody titres in cyclophosphamide (CP)-treated mouse ascitic sarcoma (Diwanay et al., 2004). CP is widely used in the treatment of a variety of malignant and non-malignant immunopathological disorders and has several side effects such as leucopenia, anaemia, etc. Since macrophages play an important role in the development of intraperitoneal adhesions, the modulation of macrophage activity would provide a new approach for the prevention and management of post-operative adhesions. *Asparagus racemosus* being reported to be an immunomodulator and immunostimulant, significantly decreased the adhesion scores by increasing macrophage phagocytosis by more than 50% in experimental animals treated with the plant extract (Rege et al., 1989). It was demonstrated that a combination of *Asparagus racemosus*, *Withania somnifera* and *Tinospora cordifolia* extracts protected mice against CP induced neutropenia. Pre-treatment for 15 days with these drugs produced a striking leucocytosis with a predominant neutrophilia. The leucopenia and specifically neutropenia induced by CP was significantly reduced by the plant extract. The total WBC and absolute neutrophil counts following the treatment with *Asparagus racemosus* had risen very high (18800 ± 2001, 13366 ± 501.96, respectively) such that the percentage fall after CP administration (63.77% total counts, 58.13% neutrophil counts) was greater than that in the control group (43.78%, 25.18%, respectively) (Dhuley, 1997). In addition, it was found that *Asparagus racemosus*, *Withania somnifera* and *Tinospora cordifolia* along with *Picrorhiza kurrooa* significantly inhibited carcinogen ochratoxin-induced suppression of chemotactic activity and production of interleukin-1 and TNF-α by macrophages (Thatte et al., 1987).

The role of *Asparagus 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 (Canadian AIDS Treatment

Information Exchange, 2005). It is in situations like these that the function of *Asparagus racemosus* as an immunoadjuvant can be scrutinized for use in adjuvant therapy in the management of HIV.

4.9. Antitussive effects

In yet another isolated report the methanol extract of *Asparagus 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 (Mandal et al., 2000a). This action has not been well documented and can be worked upon further.

5. 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 centres 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 (Tewari, 2000). 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, 2000). 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 *Asparagus 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 *Asparagus racemosus*, there is an almost 100% mark up in price from the collector level to the user (Tewari, 2000). The demand for *Asparagus 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% (National Medicinal Plants Board, 2003). 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 plants in urgent need for conservation to subvert the threat of extinction (National Medicinal Plants Board, 2002). *Asparagus racemosus* is one of the plants that figures high on this list. It has also been named as a species of the Middle Himalayas in need of conservation by the Government of Uttaranchal, India (Medicinal Plants Cultivation, 2002).

6. Challenges in conservation and sustainable use of *Asparagus racemosus*

Due to its multiple uses, the demand for *Asparagus racemosus* is constantly on the rise; however the supply is rather erratic and inadequate. Destructive harvesting combined with habitat destruction in the form of deforestation adds to the magnitude of the problem. All of this has resulted in the drastic shrinkage of its population.

In nature, the species is propagated through seeds in March–April (Tewari, 2000). Apart from this method, *Asparagus racemosus* can also be propagated vegetatively but this is a very slow and laborious technique. Irrespective of the mode of propagation the plant is ready for harvesting only by the third year. Hence, this is not an effective solution to meet the growing demand for this plant.

Considering the escalating demands of the market for a continuous and uniform supply of the plant material, and the increasing depletion of the forest resource base, cultivation of the plant rather than collection from wild will be an effective strategy. However, the basis for a sound conservation strategy would lie not only in increasing the area under cultivation, but also in attaining greater productivity to ensure reasonably higher financial returns to the growers.

7. The way forward

A multi-pronged approach to sustain the resource base that includes *in sit*u and *ex situ* conservation and selection of superior genotypes followed by their multiplication (by both conventional and biotechnological approaches) could well provide a viable solution to the problem.

7.1. Biotechnological interventions

Since the value of medicinal plants lies in the amount of the active principle present in it, it would be desirable to undertake cultivation of superior clones (recognized as 'elite'). These elites can be identified by chemo-profiling and by the use of various molecular marker techniques. Thereafter, either or both tissue culture techniques and conventional methods of propagation can be applied to multiply the plant for conservation as well as for raising commercial plantations.

Micropropagation is a viable alternative for species which are difficult to regenerate by conventional methods; where populations have decreased due to over exploitation by destructive harvesting; where there is a lot of variability in terms of the active principles present, and, where elites have been identified based on their potential for yielding higher amount of active principle. This technology can effectively be used to meet the growing demand for clonally uniform elite plants of *Asparagus racemosus*. The authors have developed an efficient *in vitro* protocol for the micropropagation of *Asparagus racemosus* through axillary branching method (unpublished).

Besides micropropagation, cell suspension culture systems could be used for large-scale production of plant cells from which secondary metabolites could be extracted. This method could function as a continuous and reliable source for the production of medicinally important compounds. Cell culture systems have several major advantages over the conventional cultivation of whole plants as it is independent of geographical and seasonal variations; it offers a defined production system ensuring a continuous supply of good quality products of high yield; it is independent of space constraints; it is possible to produce novel compounds not found in the parent plant; it allows for automated control of cell growth and regulation of metabolite processes which in turn will reduce labour costs and in the process improve productivity; and, it enables efficient downstream recovery of the product. In addition, at times the amount of secondary metabolites produced in cell cultures is considerably higher than in the natural plant system. Using the HPTLC system, Asmari et al. (2004) showed that in *Asparagus racemosus*, the highest amount of sarsasapogenin (0.133%) was present in shoot tumour followed by root callus (0.127%) and these levels were 2.59 and 2.5 times higher than the natural roots respectively. Synthesis of sarsasapogenin in the callus cultures of *Asparagus racemosus* was also reported earlier by Kar and Sen (1985).

7.2. Cultivation practices

Cultivation has several advantages over collection from the wild. Due to genetic and environmental differences, wild harvested plants normally vary in quality and consistency which seriously compromises economic returns.

Local environmental conditions strongly influence the efficacy of medicinal plants. A plant may grow well under different conditions but might fail to produce the active constituents of interest since temperature, rainfall, day length and soil characteristics are some of the factors that affect the potency of medicinal plants. These are some parameters that need to be studied well before arriving at suitable agro-techniques.

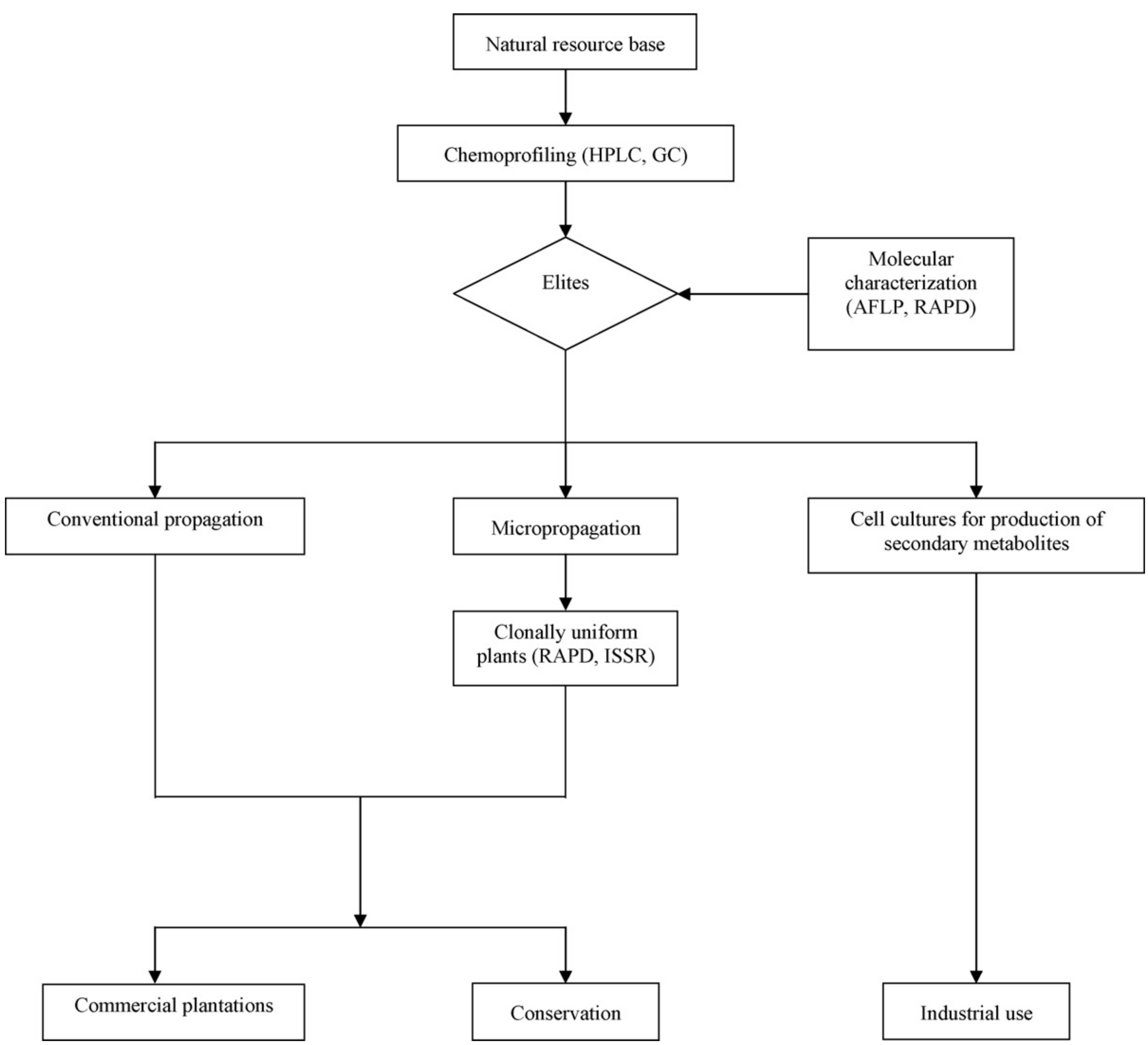

Fig. 2. Multifaceted strategy for the conservation and sustainable utilization of *Asparagus racemosus*.

7.3. Organic cultivation

Superior quality planting material produced through micropropagation in conjunction with use of bio-fertilizers (mycorrhiza), biopesticides and improved agro-techniques would augment the yields even further and generate consistently higher financial returns to the growers. In addition, since plants propagated by organic farming are preferred in the market, this would also encourage cultivation which would in the long run complement the conservation process.

7.4. Post-harvest handling

The quality of medicinal plants depends on the geographical origin, time and stage of growth when collection has been made and the manner of post-harvest handling. In India, villagers who are the major collectors of herbal material pay little attention to quality during harvesting, handling and storage. It has been reported that stored herbal drug samples very often harbour mycotoxin-producing fungi. Detection of mycotoxins has been reported in stored roots and rhizomes of *Asparagus racemosus* to the tune of 0.16 μg/g plant material. Such herbal drugs containing mycotoxins above the acceptable limit fixed by the WHO for human consumption would be rejected in the global market (Dubey et al., 2004). Efforts should therefore be made to promote sustainable management of medicinal plants at the community level itself by emphasizing on the improvement of collection, cultivation and marketing practices.

The trade and economics of *Asparagus racemosus* is affected by the presence of adulterants such as roots of *Asparagus officinalis* and *Asparagus lucidus* (syn. *Asparagus cochinchinensis*). According to the British Pharmacopoeia, the substance-specific requirements for *Asparagus racemosus* dried roots include, less than 10% loss on drying, less than 1% foreign matter, less than 5% total ash, less than 0.6% acid-insoluble ash, more than 40% ethanol soluble extractive (45% ethanol), more than 34% water soluble extractive, less than 10 ppm total heavy metals and less than 20 ppb aflatoxin (Australian Government Department of Health and Ageing). Consistency in quality and biological activity is crucial in ensuring the efficacy and safety of any botanical drug. Phytochemical investigations are beneficial for standardization and dose determination of herbal drugs. DNA based molecular marker techniques can be used in the identification of authentic *Asparagus racemosus* material and in the detection of adulterants in the herbal material as has been done in plants like *Artemisia annua* (Joshi et al., 2004).

Fig. 2 illustrates the complete strategy for the conservation and sustainable utilization of *Asparagus racemosus*.

8. Conclusion

The pharmacological studies conducted on *Asparagus racemosus* indicate the immense potential of this plant in the treatment of conditions such as menopausal symptoms, neurodegenerative disorders, diarrhoea, dyspepsia, etc. However, gaps in the studies conducted are apparent which need to be bridged in order to exploit the full medicinal potential of *Asparagus racemosus*.

Since most drugs containing Satavari that are available in the market are in the form of polyherbal formulations, it is difficult to attribute a particular medicinal action as being solely due to the *Asparagus racemosus* component of the drug. Aside from possible synergistic effects existing among the plant extract constituents, another likelihood could be the formation of ‘pro-drugs’ which are defined as compounds activated in the body after the administration of a particular medicine. Also, plant extracts are always complex mixtures composed of multiple components and therefore unless proper investigations are conducted there would be no method to connect a particular constituent vis-à-vis a specific action within the biological system. In several instances the authors have only ‘hypothesized’ (Rege et al., 1989, Dalvi et al., 1990) on the rationale behind a certain function and therefore further research is imperative to delve into the actual mode of action responsible for the medicinal effect. While most of the research has been *in vivo* which has helped to validate the applicability on the human system; *in vitro* studies would have facilitated a better understanding of the mode of action of *Asparagus racemosus*. Due to the non-availability of commercial Shatavarin standards, most studies first involve the extraction and purification of the active principle to be used as a reference standard which makes the process more cumbersome. The availability of authentic metabolite standards would not only hasten secondary metabolite assays but also make the results more reliable and reproducible.

All of these issues can be addressed by adopting a ‘systems biology’ approach wherein a very large number of components (at the levels of genome, transcriptome, proteome or metabolome as well as physiological parameters such as blood pressure, etc.) are catalogued and statistical methods are used to infer correlations to understand mechanisms of action. A key technology in systems biology is ‘metabolomics’. Metabolomics refers to the exhaustive profiling (identification, analysis and quantification) of the ‘metabolome’ which includes all the metabolites in a cell. It is a complex interdisciplinary field of research that requires a combination of bioscience, analytical chemistry, organic chemistry, chemometrics and informatics (Fukusaki and Kobayashi, 2005). Strategies for metabolomics analysis can include the metabolite profiling of *Asparagus racemosus* by identification and quantification of pre-defined metabolites by chromatographic separations (by high performance liquid chromatography, gas chromatography, and electrophoresis) followed by spectroscopic detection (by mass spectrometry or nuclear magnetic-resonance spectrometry). Metabolic fingerprinting should be done for sample classification purposes to ensure purity and avoid deliberate or inadvertent adulteration with material from other *Asparagus* species. Metabolite target analysis to perform a qualitative and quantitative study of a metabolite related to a particular metabolic reaction can be performed by chromatographic methods and mass spectrometric or ultraviolet detection. Also, an evaluation of biological fluids and tissues can be conducted to note changes in endogenous metabolite levels resulting from therapeutic treatments (a strategy termed as ‘metabonomics’).

Another shortcoming observed in several studies is that the level of statistical significance does not find any mention and hence the efficacy of the drug or plant extract cannot be commented upon even by the reviewers. Although there have been no adverse reports regarding the pharmacological actions of *Asparagus racemosus* in human beings. Goel et al. (2006) 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 *Asparagus racemosus*.

Asparagus racemosus remains a species with tremendous potential and although considerable work has been done to exploit the biological activity and medicinal applications of this plant, countless possibilities for investigation still remain in relatively newer areas of its function. As more uses of this plant are identified, the pressure on existing natural populations would increase further. Since the value of medicinal plants depends mainly on the active principle present in it; consistency in quality and quantity of planting material assumes paramount importance. This can be ensured by identifying elites through the application of molecular marker techniques and chemoprofiling followed by mass multiplication using both conventional and biotechnological approaches. Furthermore, optimization of climatic conditions and development of appropriate agro-techniques would enhance the quality and quantity of the overall produce thereby assuring a higher remuneration to the growers. This in turn would encourage farmers to undertake commercial cultivation of *Asparagus racemosus* thus curbing the overexploitation of this plant in the wild and thereby complement the conservation process.

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