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Anticancer Potential of *Asparagus racemosus* (Shatavari): A Review

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ABSTRACT

Cancer remains one of the most pressing health challenges worldwide, with conventional treatments often accompanied by significant side effects and limited efficacy in certain cases. In this context, the exploration of natural remedies and alternative therapies has gained momentum. One such promising candidate is *Asparagus racemosus*, commonly known as Shatavari. This medicinal plant, revered in traditional Ayurvedic medicine, is known for its potential therapeutic properties, including anticancer activity. This review aims to explore nutritional and anticancer properties of *Asparagus racemosus* roots. *Asparagus racemosus* has a rich history of medicinal use, particularly in Ayurveda, where it is prized for its adaptogenic, immunomodulatory, and rejuvenating properties. Recent scientific research has begun to validate these traditional claims, identifying various bioactive compounds in Shatavari that exhibit promising anticancer activities. Understanding the full spectrum of its therapeutic potential is crucial, especially in light of the growing interest in plant-based treatments and the need for safer, more effective cancer therapies.

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Cancer: A Global Health Challenge

Epidemiology of cancer: prevalence, mortality, and morbidity.

Cancer remains one of the most significant global health challenges, characterized by its high prevalence, considerable mortality rates, and substantial morbidity. **According to the World Health Organization (WHO), cancer is the second leading cause of death worldwide,** responsible for approximately 10 million deaths in 2020, accounting for nearly one in six deaths globally **(WHO, 2024).** The prevalence of cancer has been rising steadily, with an estimated 19.3 million new cases diagnosed in 2020 alone **(International Agency for Research on Cancer (IARC)).** This increase is attributed to several factors, including aging populations, lifestyle changes, and environmental influences. The most commonly diagnosed cancers include breast, lung, colorectal, prostate, and stomach cancers, each contributing significantly to the global cancer burden.

Mortality rates from cancer vary widely depending on the type of cancer, stage at diagnosis, and geographic location. Lung cancer remains the leading cause of cancer death, responsible for about 1.8 million deaths annually, followed by colorectal, liver, stomach, and breast cancers **(Mattiuzzi 2019).** The disparity in cancer mortality rates across different regions highlights the inequities in healthcare access, early detection, and treatment options. High-income countries tend to have better cancer survival rates due to advanced screening programs, early diagnosis, and more effective treatment modalities. In contrast, low- and middle-income countries such as India faces higher mortality rates, often due to late-stage diagnosis and limited healthcare resources**.**

The morbidity associated with cancer encompasses both the physical and psychological impacts on patients and their families. Cancer and its treatment often lead to significant physical challenges, including pain, fatigue, and a decline in functional abilities. The psychological impact is also profound, with many patients experiencing anxiety, depression, and a diminished quality of life. The burden of cancer extends beyond the individual, affecting families and caregivers who provide essential support. Moreover, the economic burden of cancer is substantial, with direct costs related to diagnosis and treatment and indirect costs such as lost productivity and long-term disability.

Overall, the epidemiology of cancer underscores the critical need for comprehensive cancer control strategies that encompass prevention, early detection, and equitable access to effective treatments. Public health initiatives aimed at reducing risk factors, such as tobacco use, poor diet, physical inactivity, and exposure to environmental carcinogens, are essential in curbing the rising incidence of cancer. Additionally, strengthening healthcare systems to provide timely and affordable cancer care, particularly in resource-limited settings, is vital in reducing cancer-related mortality and morbidity. Continued research and innovation in cancer prevention, diagnosis, and treatment are imperative to addressing this growing global health challenge.

Conventional Cancer Treatments and their limitations

Conventional cancer treatments, including surgery, radiation therapy, chemotherapy, immunotherapy, and targeted therapy, have significantly advanced over the past few decades. Surgery is often used to remove tumors, while radiation therapy uses high-energy particles to destroy cancer cells **(Vaidya JS, 2024).** Chemotherapy involves the use of powerful drugs to kill rapidly dividing cells, and immunotherapy enhances the body's immune system to fight cancer **(Dhar 2021)**. Targeted therapy uses drugs to target specific molecules involved in cancer growth and spread **(Lee 2018).** Despite their effectiveness, these treatments come with several limitations and challenges.

One major limitation is the adverse side effects associated with conventional treatments. Chemotherapy and radiation therapy, for instance, not only target cancer cells but also affect healthy cells, leading to side effects such as nausea, fatigue, hair loss, and increased susceptibility to infections **(Yazbeck 2022)** . Additionally, some cancers develop resistance to chemotherapy drugs, rendering the treatment ineffective over time. Immunotherapy, while promising, can cause severe immune-related side effects, including inflammation and autoimmunity **(Jamal 2020)**.

Another significant challenge is the issue of accessibility and cost. Advanced cancer treatments are often expensive and may not be readily available in low- and middle-income countries such as India. This disparity leads to differences in cancer outcomes and survival

rates across different regions.

In summary, while current cancer treatment modalities like chemotherapy, radiation therapy, surgery, and immunotherapy have significantly improved cancer survival rates, they are not without limitations. These challenges underscore the need for continued research into alternative and complementary treatments, such as those derived from medicinal plants like Asparagus racemosus, which may offer additional benefits with fewer side effects.

In this context, Ayurveda and traditional medicines have gained attention for their potential role in cancer prevention and treatment**.** Ayurveda, a traditional system of medicine practiced in India, emphasizes the use of natural products, dietary regulations, and holistic health approaches. Medicinal plants such as *Asparagus racemosus* (Shatavari) are integral to Ayurvedic medicine. Shatavari is known for its immunomodulatory, antioxidant, and anti-inflammatory properties, which can be beneficial in cancer management (Patil 2024).

Studies have shown that Shatavari possesses potential anticancer properties. Its root extracts contain bioactive compounds like saponins, flavonoids, and polyphenols that exhibit cytotoxic effects against cancer cells and can enhance the efficacy of conventional treatments while reducing their side effects **(Patil 2024)**. Shatavari has been traditionally used to improve vitality and support the immune system, making it a valuable adjunct in cancer therapy.

Medicinal Plants in Cancer Treatment

Historical Perspective on Medicinal Plants

The use of medicinal plants for treating various ailments dates back thousands of years and spans across many cultures worldwide. Ancient civilizations, including those in Egypt, China, India, and Greece, documented the therapeutic properties of plants in their traditional medical systems **(Balkrishna 2024)**. In Ayurveda, plants have been used to treat a range of diseases, including cancer (**Kuruppu 2019; Lopus 2023; Saxena 2024)**. These traditional systems often relied on the holistic properties of plants, which were believed to restore balance and promote overall health. The historical use of medicinal plants laid the foundation for modern pharmacology and continues to inspire contemporary research into their potential benefits in cancer treatment.

Mechanisms of Action of Plant-Derived Compounds in Cancer Therapy

Medicinal plants contain a diverse array of bioactive compounds that exhibit multiple mechanisms of action against cancer cells (FIGURE 1). These mechanisms can be broadly categorized into antioxidant activity, anti-inflammatory effects, and cytotoxicity to cancer cells (Figure 1).

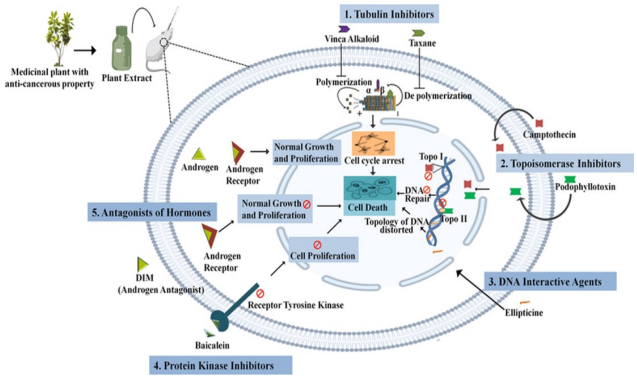


Figure 1: Mechanism of action of various natural compounds against cancer (Upreti 2022)

Antioxidant Activity

Many plant-derived compounds possess strong antioxidant properties, which help neutralize free radicals and reduce oxidative stress in the body **(Akbari 2022; Cui 2020; Pisoschi 2016; Girgih2024)**. Oxidative stress is a key factor in the initiation and progression of cancer, as it can cause DNA damage, promote mutations, and enhance cancer cell survival **(Iqbal 2024)**. Antioxidants from plants, such as flavonoids, polyphenols, and vitamins, can Protect cellular DNA from damage **(Navyashree R 2024; Nisha 2011),** Inhibit the proliferation of cancer cells **(Zhang 2015)**, Enhance the body's natural defense mechanisms against oxidative damage **(Adwas 2019)**.

For example, compounds like quercetin and resveratrol, found in various fruits and vegetables, have shown significant antioxidant and anticancer properties in preclinical studies **(Aggarwal 2004; Del 2016; Mrkus 2019; Cecerska- 2024)**.

Here is a table listing some plant-derived compounds that possess strong antioxidant proper-

ties which help protect cells from oxidative damage and support overall health.

Table 1. Natural antioxidant compounds

Compound	Source Plants	Antioxidant Properties	
Quercetin	Onions, apples, berries	Scavenges free radicals, inhibits lipid peroxidation	**(Jin 2021)**
Catechins	Green tea, cocoa	Reduces oxidative stress, protects against cellular damage	**(Bernatoniene 2018)**
Resveratrol	Grapes, berries	Protects against oxidative damage, anti-inflammatory effects	**(Vikal 2024)**
Curcumin	Turmeric	Inhibits oxidative stress, anti-inflammatory, scavenges free radicals	**(Boroumand 2018)**
Epigallocatechin gallate (EGCG)	Green tea	Potent free radical scavenger, protects cells from damage	**(Tobi 2002)**
Lycopene	Tomatoes, watermelon	Neutralizes free radicals, reduces oxidative stress	**(Kim 2014; Boulaajine 2024)**
Anthocyanins	Berries, red cabbage	Antioxidant and anti-inflammatory effects	**(Godyla 2024)**
Beta-carotene	Carrots, sweet potatoes	Scavenges free radicals, protects cells from oxidative damage	**(Paiva 1999)**
Genistein	Soybeans	Antioxidant activity, inhibits lipid peroxidation	**(Li 2024)**
Ellagic acid	Pomegranates, berries	Neutralizes free radicals, protects DNA from oxidative damage	**(Baradaran 2020; De 2020)**
Lutein	Kale, spinach	Scavenges free radicals, protects eyes from oxidative stress	**(Srividya 2014)**
Apigenin	Parsley, chamomile	Inhibits oxidative stress, anti-inflammatory effects	**(Mushtaq 2023)**

Anti-inflammatory Effects

Chronic inflammation is a well-established risk factor for the development and progression of cancer **(Fernandes 2023)**. Inflammatory processes can create a microenvironment that supports tumor growth, angiogenesis, and metastasis **(Yang 2017; de Visser 2023)**. Many medicinal plants contain anti-inflammatory compounds that can modulate these processes and reduce the risk of cancer. These compounds work by: Inhibiting pro-inflammatory cytokines and enzymes (e.g., COX-2, NF-κB); Reducing the production of reactive oxygen species (ROS); Modulating immune responses to create an anti-tumor environment **(Tasneem 2019).** Curcumin from turmeric and boswellic acid from frankincense are notable examples of plant-derived compounds with potent anti-inflammatory and anticancer activities.

Traditional medicinal systems and Integration of Asparagus racemosus (Shatavari) in Oncology

India is well known for its well-documented traditional medical systems, such as Siddha, Unani, and Ayurveda **(Pravin et al., 2023).** The historical relevance of these medicinal systems is indicated by their reference in ancient Vedas and scriptures **(Veale et al., 2020; John, 2021; Anesini et al., 2021).** With its literal definition translating to "science of life," Ayurveda originated and flourished in India between 2500 and 500 BC, emphasizing holistic perspectives on health and illness **(Subhose et al., 2018).** Known as the "science of longevity," Ayurveda provides holistic methods to support long-term health via dietary changes and therapeutic techniques **(Rabe et al., 2018; Samy, 2019)**. Ayurvedic diet, while effective in treating a variety of conditions, emphasizes patient empowerment and self-responsibility, and requires active patient participation for good results. On the other hand, contemporary eating patterns have caused nutritional imbalances, which have upset everyday routines**.** People prioritize wellness over traditional sick care due to this imbalance, further exacerbated by changing lifestyles and limited access to healthcare**.**

The integration of Shatavari in oncology could offer a complementary approach to cancer treatment, focusing on enhancing the body's natural defense mechanisms and overall well-being**.**

Introduction to *Asparagus racemosus* (Shatavari) and its traditional uses

Asparagus racemosus, commonly known as Shatavari, is a perennial climbing plant belonging to the family Asparagaceae **(Rafiq 2023)**. It is well-known in traditional

Ayurvedic medicine for its wide range of therapeutic properties. Here is a detailed botanical description and information on its distribution.

Appearance: Asparagus racemosus is characterized by its thorny, wiry, and spiny stems which can grow up to 1-2 meters in length **(Rafiq 2023)**. The plant has a climbing or trailing habit, often supported by surrounding vegetation. The leaves of Shatavari are reduced to small scales called cladodes. These cladodes are green, needle-like, and arranged in clusters, giving the plant a feathery appearance. One of the most distinctive features of Asparagus racemosus is its extensive root system. The roots are tuberous, succulent, and fusiform, often growing in clusters. These roots are used medicinally and can vary in size depending on the age of the plant. The plant produces small, fragrant, white or pale green flowers that are arranged in dense, racemose inflorescences. These flowers are typically hermaphroditic, containing both male and female reproductive organs. The fruit of Shatavari is a small, globular berry that turns red upon ripening. Each berry contains one to two seeds.

Distribution: Asparagus racemosus is native to the Indian subcontinent and can be found throughout India, Sri Lanka, Nepal, and the Himalayas. It grows in tropical and subtropical regions and is also found in parts of Africa and Southeast Asia **(Thakur 2021)**. Shatavari thrives in a variety of habitats, including forested areas, grasslands, and rocky soils. It is commonly found in shaded, well-drained areas and can grow at elevations ranging from sea level to 1,500 meters **(Bharati 2019)**. While Shatavari grows wild in many regions, it is also cultivated for its medicinal roots. The plant prefers sandy loam soils with good drainage and can tolerate a range of climatic conditions, although it flourishes best in regions with moderate rainfall and temperatures **(Singla 2014).**

Traditional Uses of Asparagus racemosus

In Ayurvedic medicine, Asparagus racemosus, commonly known as Shatavari, holds a revered position due to its wide range of health benefits. The name "Shatavari" translates to "one who possesses a hundred husbands," indicating its traditional use as a female reproductive tonic. Key uses in Ayurveda include:

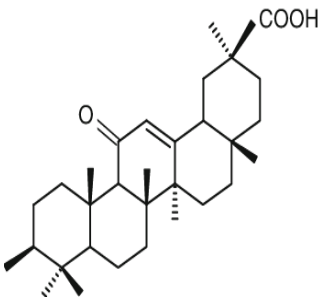
Reproductive Health: Shatavari is considered a premier herb for supporting female reproductive health. It is used to balance hormones, enhance fertility, and alleviate symptoms of menopause and premenstrual syndrome (PMS). It is also believed to support lactation in nursing mothers **(Thakur 2021)**.

Digestive Health: Shatavari is used to treat various digestive issues, such as dyspepsia, gastric ulcers, and irritable bowel syndrome (IBS). It is known for its cooling and soothing properties, which help reduce inflammation and promote healthy digestion **(Perera 2019)**.

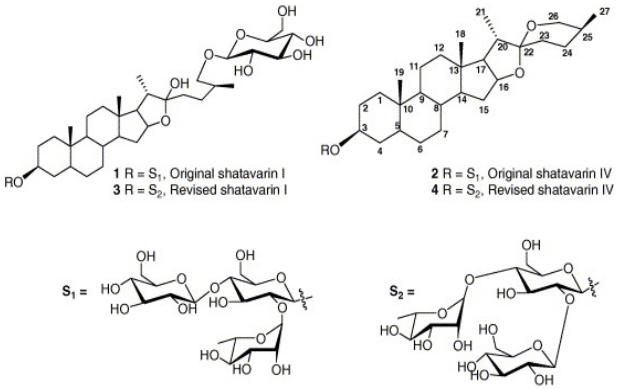
Immunomodulation: It is valued for its ability to strengthen the immune system. Shatavari is used to enhance overall vitality and resilience against infections and diseases **(Hooda 2024)**.

Phytochemical composition of Asparagus racemosus roots

Asparagus racemosus (Shatavari) is renowned for its rich phytochemical composition, which contributes to its wide array of therapeutic effects. The key phytochemical groups present in the roots include saponins, alkaloids, flavonoids, sterols, and other important constituents like polyphenols, vitamins, and minerals **(Selvaraj 2019)**.



Saponin



Shatavarins

Here is a table summarizing the phytochemical composition of *Asparagus racemosus* (Shatavari) roots and their medicinal effects

Table 2. Phytochemical composition of Asparagus racemosus

Phytochemical	Category	Medicinal Effect	
Saponins	Glycosides	Immunomodulatory, anti-inflammatory, antioxidant	**(Sharma 2013)**
Shatavarins (I-IV)	Steroidal saponins	Adaptogenic, supports reproductive health, boosts immunity	**(Sharan 2020)**
Flavonoids	Polyphenols	Antioxidant, anti-inflammatory, cardioprotective	**(Kapoor 2019)**
Alkaloids	Nitrogen-containing compounds	Antimicrobial, anti-inflammatory	**(Selvaraj 2019)**
Oligosaccharides	Carbohydrates	Prebiotic effects, supports digestive health	**(Hor 2022)**
Sterols (e.g., Sitosterol)	Phytosterols	Cholesterol-lowering, anti-inflammatory	**(Selvaraj 2019)**
Isoflavones	Polyphenols	Antioxidant, supports hormonal balance	**(Kohli 2023)**
Tannins	Polyphenols	Astringent, antimicrobial, antioxidant	**(Singh 2018)**

Anticancer Potential of Asparagus racemosus

Shatavari, has garnered attention for its potential anticancer properties, attributed largely to its rich array of bioactive compounds. Numerous studies have explored the mechanisms through which Shatavari exerts its anticancer effects, focusing on its phytochemicals such as saponins, flavonoids, and alkaloids.

Several preclinical studies have demonstrated the efficacy of Shatavari extracts in inhibiting the growth of various cancer cell lines. For instance, a study by **Gupta *et al.* (2022)** found that the saponins extracted from Shatavari roots induced apoptosis in human breast cancer cells (MCF-7) through the activation of caspase pathways. This pro-apoptotic activity was linked to the upregulation of p53, a crucial tumor suppressor protein, and the downregulation of anti-apoptotic proteins such as Bcl-2 (**Gupta *et al.* 2022)**.

Another significant study conducted by **Biswas *et al.*, 2018;** investigated the effects of Shatavari extracts on lung cancer cells. The researchers observed a dose-dependent inhibition of cell proliferation in A549 lung cancer cells. This antiproliferative effect was mediated by the induction of cell cycle arrest at the G2/M phase, suggesting a disruption of cellular mitosis. The study also highlighted the antioxidant properties of Shatavari, which contribute to its ability to neutralize reactive oxygen species (ROS), thereby protecting cells from oxidative stress and potential carcinogenesis.

In vivo studies have further validated the anticancer potential of Shatavari. Research by **Mitra *et al.* 2012;** involved administering Shatavari root extract to mice with induced Ehrlich ascites carcinoma. The treatment significantly reduced tumor volume and weight, enhanced the lifespan of the treated mice, and improved their overall health. The anticancer efficacy was attributed to the immunomodulatory effects of Shatavari, which enhanced the production of cytokines such as interferon-gamma (IFN-γ) and interleukin-2 (IL-2), thereby boosting the immune response against the tumor cells.

The mechanisms underlying Shatavari's anticancer activity are multifaceted, involving apoptosis induction, cell cycle arrest, antioxidant activity, and immunomodulation. These findings highlight the potential of Shatavari as a complementary therapy in cancer treatment. However, it is crucial to conduct further research, including clinical trials, to validate these preclinical findings and to fully under-

stand the therapeutic potential and safety profile of Shatavari in cancer management.

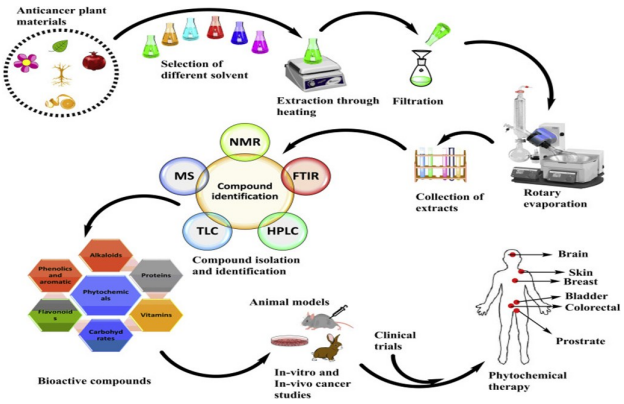


Figure 2. Detailed scheme of anticancer phytochemical synthesis, optimization, characterization and prospective use as cancer therapeutic agent. (Iqbal 2017)

Mechanism of Action of Anticancer Potential of Asparagus racemosus

The anticancer potential of *Asparagus racemosus* (Shatavari) is primarily attributed to its diverse phytochemical composition, which includes saponins, flavonoids, alkaloids, and antioxidants. These compounds collectively contribute to its multifaceted mechanisms of action against cancer, which include apoptosis induction, cell cycle arrest, antioxidant activity, and immunomodulation.

Induction of Apoptosis

One of the primary mechanisms through which Asparagus racemosus exerts its anticancer effects is the induction of apoptosis, or programmed cell death, in cancer cells. Saponins, particularly shatavarin IV, have been shown to trigger apoptosis in various cancer cell lines **(Mitra 2012).** This process involves:

Activation of Caspase Pathways: Key proteins like caspase-3, caspase-8, and caspase-9 are activated, leading to the systematic dismantling of the cancer cell **(Fatime 2022)**.

Regulation of Apoptotic Proteins: Shatavari extracts modulate the expression of critical apoptotic regulators, increasing pro-apoptotic proteins like Bax and decreasing anti-apoptotic proteins like Bcl2. This shift in the balance of apoptotic proteins favors cell death in cancer cells **(Kaur 2017)**.

Upregulation of p53: The tumor suppressor protein p53 is upregulated, which plays a crucial role in initiating the apoptotic process in response to cellular stress and DNA damage **(El -senosi 2021)**.

Inhibition of Cell Proliferation and Cell Cycle Arrest

Asparagus racemosus affects the cell cycle, thereby inhibiting the proliferation of cancer cells:

Cell Cycle Arrest: Studies have shown that Shatavari extracts can induce cell cycle arrest at various phases, particularly the G2/M phase **(Kaur 2017)**. This halts the division and proliferation of cancer cells by interfering with the normal progression of the cell cycle.

Inhibition of Mitotic Progression: Compounds in Shatavari disrupt the mitotic spindle formation and chromosome segregation, leading to mitotic arrest and subsequent cell death.

Antioxidant Activity

Asparagus racemosus is rich in antioxidants, which play a significant role in its anticancer activity:

Neutralization of Reactive Oxygen Species (ROS): Shatavari's antioxidants, such as flavonoids and phenolic compounds, scavenge ROS, reducing oxidative stress in cells. This is crucial as oxidative stress can lead to DNA damage and promote carcinogenesis **(Akhtara 2022)**.

Protection Against DNA Damage: By mitigating oxidative stress, Shatavari protects cellular DNA from damage, thereby preventing mutations that could lead to cancer development and progression **(Ray A 2022)**.

Immunomodulation

The immunomodulatory effects of Asparagus racemosus enhance the body's natural defense mechanisms against cancer:

Stimulation of Immune Cells: Shatavari extracts have been shown to enhance the activity and proliferation of immune cells such as T cells, natural killer (NK) cells, and macrophages **(Hooda P, 2024)**, which are vital for targeting and destroying cancer cells.

Cytokine Production: The extracts stimulate the production of key cytokines like interferon-gamma (IFN-γ) and interleukin-2 (IL-2), which enhance the immune response against tumor cells**(Hooda P, 2024)**.

Importance of *Asparagus racemosus* for Cancer Treatment

Unique Phytochemical Composition and its Relevance to Cancer Therapy

Asparagus racemosus (Shatavari) possesses a unique phytochemical composition characterized by compounds such as saponin s, alkaloids, flavonoids, and sterols. These bioactive

constituents have demonstrated promising anticancer properties in preclinical studies, including cytotoxic effects on cancer cells, induction of apoptosis, and inhibition of tumor growth and metastasis. The diverse array of phytochemicals present in Shatavari offers multiple mechanisms of action against cancer cells, making it a valuable adjunctive therapy in cancer treatment regimens.

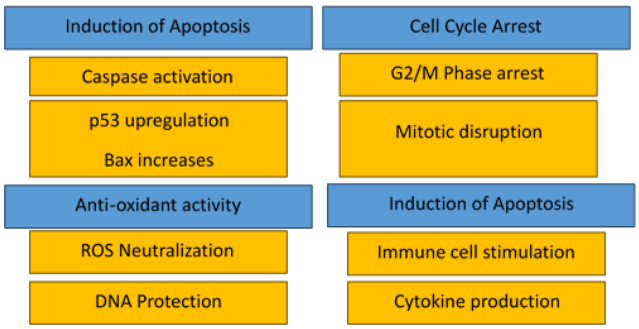


Figure 3. Visual representation of the mechanisms through which Asparagus racemosus exerts its anticancer potential

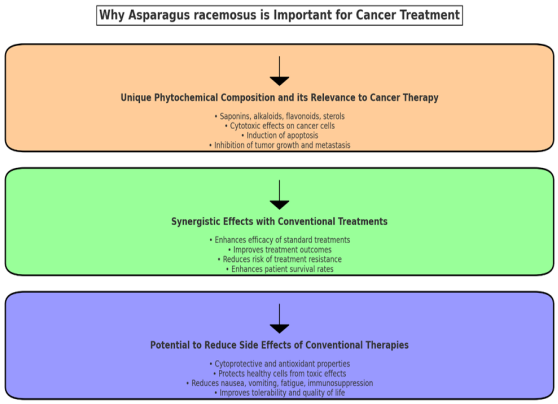
Synergistic Effects with Conventional

Emerging evidence suggests that *Asparagus racemosus* may exhibit synergistic effects when used in combination with conventional cancer treatments such as chemotherapy, radiation therapy, and targeted therapies. By enhancing the efficacy of standard treatments, Shatavari extracts have the potential to improve treatment outcomes, reduce the risk of treatment resistance, and enhance overall patient survival rates. This synergism may be attributed to complementary mechanisms of action between Shatavari and conventional therapies, highlighting its importance in multimodal cancer treatment approaches.

Potential to Reduce Side Effects of Conventional Therapies

In addition to enhancing the efficacy of conventional treatments, Asparagus racemosus has shown promise in mitigating the side effects associated with chemotherapy and radiation therapy. Studies suggest that Shatavari extracts possess cytoprotective and antioxidant properties, which may help protect healthy cells from the toxic effects of chemotherapy and reduce treatment-related adverse events such as nausea, vomiting, fatigue, and immunosuppression. By improving tolerability and quality of life during cancer treatment, Shatavari offers significant benefits to patients undergoing conventional therapies.

In conclusion, while conventional cancer treatments have made significant strides, their limitations necessitate the exploration of alternative and complementary therapies. Shatavari, with its promising anticancer properties and role in Ayurveda, represents a potential natural ally in the fight against cancer. Its incorporation into oncology could improve patient outcomes, reduce side effects, and offer a more holistic approach to cancer care. Studying *Asparagus racemosus* also aligns with the broader movement towards sustainable and natural health solutions, emphasizing the importance of integrating scientifically backed traditional knowledge into modern medical practices**.** By integrating this plant into everyday foods, we hope to uncover practical ways to harness its benefits in a dietary context, potentially offering a complementary approach to cancer prevention and treatment. Research into the anticancer effects of Shatavari and other Ayurvedic herbs continues to grow, highlighting the importance of combining traditional knowledge with modern scientific approaches to develop more effective and holistic cancer therapies. Further research and clinical trials are essential to fully understand and harness the benefits of Shatavari in cancer prevention and treatment**.**



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the manuscript.

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