**Stallion Journal for Multidisciplinary Associated Research Studies**
ISSN (Online): 2583-3340
Volume-5 Issue-2 || April 2026 || PP. 34-43 https://doi.org/10.55544/sjmars.5.2.6

# Skin Cancer and the Chemo Preventive Potential of *Catharanthus Roseus* (Sadabahar Plant): A Comprehensive Review

**Pragati Katiyar[1], Swati Trivedi[1*], Anubhav Dubey[1], Vikram Kumar Sahu[1], Sribatsa Lanchhana Dash[1] and Amit Mishra[2]**
[1]Maharana Pratap College of Pharmacy Kothi, Mandhana, Kanpur - 209217, Uttar Pradesh, INDIA.
[2]Maharana Pratap College of Pharmaceutical Sciences, Kothi, Mandhana, Kanpur - 209217, Uttar Pradesh, INDIA.

[1]Corresponding Author: swatipharma10@gmai.com

**www.sjmars.com || Vol. 5 No. 2 (2026): April Issue**

| **Date of Submission:** 01-04-2026 | **Date of Acceptance:** 10-04-2026 | **Date of Publication:** 20-04-2026 |
|---|---|---|

**ABSTRACT**

**Skin cancer, encompassing melanoma, basal cell carcinoma (BCC), and squamous cell carcinoma (SCC), represents one of the most prevalent and rapidly increasing malignancies worldwide, with more than 1.5 million new cases estimated globally in 2022. Despite advances in surgical intervention, targeted therapies, and immunotherapy, the significant side effects, high treatment costs, and drug resistance associated with conventional approaches underscore the urgent need for safer chemopreventive strategies derived from natural sources. Catharanthus roseus (L.) G. Don, commonly known as "Sadabahar" in India, is a medicinally revered member of the family *Apocynaceae* that has been a cornerstone of traditional medicine systems across Asia, Africa, and the Caribbean for centuries. The plant harbors more than 344 phytochemical compounds, including bisindole alkaloids (vinblastine, vincristine, vindesine), monoterpene indole alkaloids (catharanthine, vindoline), flavonoids (quercetin, kaempferol, rutin), phenolic acids, and volatile constituents, each endowed with remarkable pharmacological profiles. This review comprehensively examines the epidemiology and molecular pathogenesis of skin cancer, elucidates the phytochemical richness of C. roseus, and critically analyzes the chemopreventive mechanisms underlying its anticancer activity — including tubulin polymerization inhibition, apoptosis induction via caspase activation, reactive oxygen species (ROS) modulation, cell cycle arrest, anti-inflammatory activity, and antioxidant photoprotection. The review further discusses the translational potential of C. roseus-derived compounds into dermatological and oncological therapeutics, identifies key challenges such as bioavailability and toxicity, and highlights directions for future research including nanoformulations and combinatorial pharmacology.**

***Keywords-*** Catharanthus roseus; Skin cancer; Chemoprevention; Vinca alkaloids; Vinblastine; Vincristine.

## I. INTRODUCTION

Skin cancer is one of the most significant public health challenges of the 21st century, with incidence rates rising across all global regions at an alarming pace. The World Health Organization and the International Agency for Research on Cancer (IARC) estimate that skin cancers collectively represent the most commonly diagnosed group of cancers worldwide, accounting for more than 1.5 million new cases in 2022 alone (IARC, 2022). Among these, melanoma is particularly feared owing to its aggressive metastatic potential, with approximately 330,000 new cases and nearly 60,000 deaths recorded globally in 2022 (IARC, 2022). Non-melanoma skin cancers (NMSCs), including basal cell carcinoma (BCC) and squamous cell carcinoma (SCC), while less lethal than melanoma, impose an enormous burden on healthcare systems because of their sheer prevalence and high recurrence rates (Marzuka& Book, 2015).

The principal etiological driver of skin cancer is ultraviolet (UV) radiation from sunlight, which induces oxidative DNA damage, mutations in key tumor suppressor genes such as *TP53*, and immune dysregulation (Narayanan et al., 2010). Additional risk factors include ionizing radiation, chemical carcinogens, human papillomavirus (HPV) infection in certain SCC subtypes, immunosuppression, and genetic predisposition involving mutations in *CDKN2A*, *BRAF*, *NRAS*, and *KIT*

genes (Boniol et al., 2012). Conventional treatment modalities — surgery, radiotherapy, chemotherapy, targeted therapies (BRAF inhibitors such as vemurafenib), and immunotherapy (PD-1/PD-L1 checkpoint inhibitors) — have improved survival outcomes, particularly for melanoma; however, these approaches are fraught with systemic toxicities, high relapse rates, and prohibitive costs that limit their accessibility in low- and middle-income countries (Garbe et al., 2020).

Chemoprevention, defined as the use of natural or synthetic compounds to arrest, reverse, or delay the initiation, promotion, or progression of carcinogenesis, has emerged as a rational complementary strategy for managing skin cancer risk (Surh, 2003). Plant-derived phytochemicals have historically provided some of the most potent and clinically validated anticancer molecules known to medicine. Among these, *Catharanthus roseus* (L.) G. Don — popularly called "Sadabahar" (meaning "ever-flowering" or "perennial") in India, and known globally as Madagascar periwinkle — occupies a position of singular importance (Kaur et al., 2021). The plant's bisindole alkaloids, vinblastine and vincristine, have been integral to cancer chemotherapy since the 1960s and remain World Health Organization Essential Medicines to this day (WHO, 2021). Native to Madagascar and now pantropically distributed, *C. roseus* has been utilized for millennia across diverse ethnomedicinal traditions — in India within Ayurveda, Siddha, and Unani systems; in China within Traditional Chinese Medicine (TCM); and in various Caribbean and African folk systems — for conditions ranging from diabetes and hypertension to cancer and skin disorders (Das & Sharangi, 2017). Modern phytochemical and pharmacological investigations have confirmed these traditional uses and revealed a far richer repertoire of bioactive molecules than previously appreciated, encompassing more than 344 compounds across multiple chemical classes (Mukherjee et al., 2022). This review synthesizes current knowledge on the epidemiology and molecular mechanisms of skin cancer, the phytochemical architecture of *C. roseus*, and the mechanistic basis of its chemopreventive potential against skin malignancies. It also addresses pharmacological challenges and charts future directions for translational application of this valuable medicinal plant.

## II. EPIDEMIOLOGY OF SKIN CANCER

### *2.1 Global Prevalence and Incidence*

Skin cancer encompasses a heterogeneous group of malignancies that collectively constitute the most diagnosed cancer category globally. The IARC (2022) reported that worldwide incidence of all skin cancer types surpassed 1.5 million cases in 2022, with melanoma alone accounting for approximately 330,000 diagnoses. Significant geographic disparities exist: Australia and New Zealand record the highest age-standardized incidence rates (ASR) at 37.00 per 100,000 population, reflecting high UV index exposure and predominantly fair-skinned populations, followed by North America (USA: 16.50/100,000; Canada: 14.50/100,000) and Europe (Italy: 12.70/100,000; Germany: 12.10/100,000) (Veneri et al., 2024). Asian countries, including India (ASR: 0.16/100,000) and China (ASR: 0.37/100,000), report comparatively lower rates, though absolute case numbers remain substantial given population size (Veneri et al., 2024).

NMSCs, particularly BCC, are significantly more prevalent than melanoma, though they are systematically underreported in many cancer registries. BCC alone accounts for approximately 80% of all NMSC cases (Marzuka& Book, 2015). In melanoma, males are disproportionately affected across most world regions (IARC, 2022). Mortality from melanoma, though lower in absolute numbers than many other cancers, is rising due to its propensity for systemic metastasis; the survival rate for metastatic melanoma remains below 30% despite recent immunotherapy advances (Garbe et al., 2020).

### *2.2 Risk Factors*

The pathogenesis of skin cancer involves a complex interplay between environmental, genetic, and immunological risk factors. UV radiation — both UVA (315–400 nm) and UVB (280–315 nm) — is the dominant environmental carcinogen, responsible for the induction of cyclobutane pyrimidine dimers (CPDs) and 6–4 photoproducts in DNA, ultimately triggering mutagenic events (Narayanan et al., 2010). UV-B exposure specifically induces the inactivation of the *p53* tumor suppressor gene, a hallmark event in both BCC (50% of cases) and SCC (90% of cases) (Veneri et al., 2024). Genetic predisposition through mutations in *CDKN2A* (encoding tumor suppressors p14ARF and p16INK4A), *BRAF* (most commonly V600E), *NRAS*, and *KIT* gene alterations underpin melanoma susceptibility (Boniol et al., 2012). Immunosuppression, such as post-organ transplantation or HIV infection, dramatically increases SCC risk. Additional risk factors include occupational chemical exposures (arsenic, coal tar), chronic UV exposure in outdoor workers, Fitzpatrick skin phototype I–II, a history of sunburn (particularly in early childhood), and therapeutic ionizing radiation (Narayanan et al., 2010).

## III. MOLECULAR PATHOGENESIS OF SKIN CANCER

### *3.1 Melanoma*

Melanoma originates from the malignant transformation of melanocytes — pigment-producing cells derived from neural crest precursors — located predominantly at the dermoepidermal junction. The oncogenic landscape of melanoma is dominated by activating mutations in *BRAF* (particularly V600E, present in ~50% of cutaneous melanomas), *NRAS*, and less frequently *KIT*, *NF1*, and *GNAQ/GNA11* mutations (Boniol et al., 2012). UV-mediated oxidative stress generates reactive oxygen species (ROS) and direct DNA damage, leading to the inactivation of *p53* and facilitating melanocyte

immortalization. The MAPK (RAS/RAF/MEK/ERK) and PI3K/AKT/mTOR signaling pathways are constitutively activated in melanoma, driving uncontrolled proliferation, resistance to apoptosis, and invasive migration (Garbe et al., 2020). Histologically, the four major subtypes — superficial spreading melanoma (SSM, most common), nodular melanoma (NM), lentigo maligna melanoma (LMM), and acral lentiginous melanoma (ALM) — differ in growth patterns, clinical presentation, and genetic profiles, with ALM notably characterized by *KIT* mutations rather than *BRAF* alterations (Veneri et al., 2024).

### *3.2 Basal Cell Carcinoma (BCC)*

BCC arises from basal cells of the epidermis and the outer root sheath of hair follicles. The central molecular driver is dysregulation of the Hedgehog (Hh) signaling pathway, most commonly through inactivating mutations in *PTCH1* (Patched-1) or activating mutations in *SMO* (Smoothened), leading to constitutive GLI transcription factor activity and uncontrolled cell proliferation (Marzuka& Book, 2015). *TP53* mutations, largely attributable to UV-induced C→T transitions, are also universally present. BCC rarely metastasizes but causes significant local tissue destruction through invasive growth.

### *3.3 Squamous Cell Carcinoma (SCC)*

SCC develops from the keratinocytes of the stratum spinosum. *TP53* mutation is the critical initiating event, occurring in approximately 90% of invasive SCCs (Veneri et al., 2024). Progressive accumulation of UV-induced mutations in genes such as *NOTCH1*, *NOTCH2*, *CDKN2A*, and *HRAS* drives progression from actinic keratosis (premalignant precursor) to carcinoma in situ and finally invasive SCC. Unlike BCC, SCC carries a tangible risk of lymph node and distant metastasis, particularly in immunocompromised individuals (Narayanan et al., 2010).

### *3.4 The Role of Oxidative Stress and Inflammation*

Chronic oxidative stress and inflammation are unifying pathogenic features shared across all skin cancer subtypes. UV-induced ROS generation leads to lipid peroxidation, protein oxidation, and oxidative DNA damage including 8-hydroxydeoxyguanosine (8-OHdG) adducts, which drive mutagenesis (Narayanan et al., 2010). Concurrently, UV radiation activates NF-κB, AP-1, and STAT3 transcription factors, promoting a pro-inflammatory tumor microenvironment enriched in IL-6, TNF-α, and cyclooxygenase-2 (COX-2), all of which facilitate carcinogenesis (Surh, 2003). These pathways are pharmacologically accessible targets for chemopreventive natural compounds.

## IV. *CATHARANTHUS ROSEUS*: BOTANICAL PROFILE AND TRADITIONAL USES

### *4.1 Taxonomy and Botanical Description*

*Catharanthus roseus* (L.) G. Don is a short-lived perennial herb and member of the family Apocynaceae (subfam. Rauvolfioideae). Formerly classified within the genus *Vinca* and widely referred to as *Vinca rosea*, it has been taxonomically reclassified based on molecular phylogenetic studies (Kaur et al., 2021). The plant is native to Madagascar but has been cultivated pantropically owing to its ornamental value, hardiness, and medicinal importance. Morphologically, *C. roseus* is characterized by opposite, glossy, oblong-elliptic leaves with a prominent midrib, five-petaled flowers available in white, pink, red, and bicolored varieties, and a milky, bitter latex in all parts (Mukherjee et al., 2022). In India, it is commonly known as "Sadabahar" (meaning "evergreen" or "perennial bloomer"), reflecting its year-round flowering habit under tropical conditions. The plant thrives in well-drained soils across India, Pakistan, Nepal, and other tropical and subtropical nations (Kaur et al., 2021).

### *4.2 Ethnomedicinal and Traditional Uses*

The ethnopharmacological legacy of *C. roseus* spans multiple continents and medical traditions. In the Indian Ayurvedic system, different plant parts (leaves, stems, flowers, roots) are employed for treating helminthiasis, digestive disorders, hypertension, diabetes mellitus, and various cancers (Das & Sharangi, 2017). In Siddha and Unani traditions, the plant is used as an emetic, laxative, stomachic, and sedative, and for the management of toothache and menstrual irregularities (Mukherjee et al., 2022). Traditional Chinese Medicine (TCM) employs *C. roseus* preparations for antitumor and antidiabetic effects. In the Caribbean and Philippines, leaf decoctions were historically used for diabetes management — a use that serendipitously led to the isolation of the vinca alkaloids during anti-diabetic drug screening in the 1950s (Wikipedia, 2024). In Australia, England, and Japan, the plant has also been used for gonorrhea, wasp stings, and hypertension (Kaur et al., 2021). Indigenous communities in West Africa use the plant for wound healing and skin infections — applications that directly intersect with dermatological pharmacology (Mukherjee et al., 2022).

## V. PHYTOCHEMICAL CONSTITUENTS OF *CATHARANTHUS ROSEUS*

### *5.1 Alkaloids: The Primary Bioactive Fraction*

*C. roseus* is among the most phytochemically prolific medicinal plants known, with more than 344 compounds identified across its various plant parts (Mukherjee et al., 2022). The alkaloids constitute the most pharmacologically significant fraction and are broadly classified into monoterpene indole alkaloids (MIAs) and bisindole alkaloids.

- **Bisindole Alkaloids:** Vinblastine and vincristine — the crown jewels of anticancer pharmacology — are dimeric MIAs biosynthesized in *C. roseus* from the coupling of two monomeric precursors: catharanthine and vindoline (Miettinen et al., 2019). The plant synthesizes vinblastine and vincristine through a complex 26-step biosynthetic pathway uniquely present in *C. roseus* (Miettinen et al., 2019). Vindesine, a semi-synthetic derivative of vinblastine, is also produced from this pathway. These bisindole alkaloids have been used clinically since the 1960s for treating Hodgkin's disease, testicular cancers, lymphoblastic leukemia, and melanoma (Szabó et al., 2019).
- **Monomeric MIAs:** The plant produces over 100 MIAs, of which approximately 70 are pharmacologically active (Szabó et al., 2019). Key monomeric alkaloids include catharanthine, vindoline, ajmalicine (raubasine), serpentine, lochnericine, and tabersonine. Catharanthine and vindoline, localized predominantly in leaf tissue, are the direct biosynthetic precursors of the anticancer bisindole alkaloids (Miettinen et al., 2019). Ajmalicine exhibits antihypertensive and sedative properties, while serpentine is noted for its cytotoxic and antifungal activity (Mukherjee et al., 2022).

### *5.2 Flavonoids and Phenolic Compounds*

Comprehensive HPLC-DAD analysis of *C. roseus* extracts has identified a rich array of flavonoids and phenolic acids, including catechin hydrate, (-)-epicatechin, rutin hydrate, quercetin, kaempferol, isorhamnetin, trans-cinnamic acid, trans-ferulic acid, vanillic acid, and catechol across multiple plant parts (Ahmed et al., 2024). Three caffeoylquinic acids and fifteen flavonol glycosides (di- and trisaccharides of kaempferol, quercetin, and isorhamnetin) have been characterized in detail; petals were identified as the part with the highest antioxidant activity using DPPH radical scavenging and reactive oxygen/nitrogen species (ROS/RNS) neutralization assays (Ferreres et al., 2008). These phenolic compounds are of direct relevance to skin cancer chemoprevention because of their potent antioxidant, anti-inflammatory, and antiproliferative properties (Ahmed et al., 2024).

### *5.3 Terpenes, Saponins, and Volatile Constituents*

Beyond alkaloids and flavonoids, *C. roseus* yields saponins, carbohydrates, sterols (β-sitosterol, stigmasterol), ursolic acid, oleanolic acid, and an extensive array of 156 volatile constituents that collectively contribute to the plant's broad pharmacological spectrum (Mukherjee et al., 2022). Ursolic acid and oleanolic acid are pentacyclic triterpenes with documented anti-inflammatory, antitumor, and anti-angiogenic properties, further enriching the chemopreventive portfolio of the plant (Surh, 2003).

| Phytochemical Class | Key Compounds | Primary Biological Activity |
|---|---|---|
| Bisindole alkaloids | Vinblastine, vincristine, vindesine | Antimitotic, anticancer, antileukemic |
| Monomeric MIAs | Catharanthine, vindoline, ajmalicine, serpentine, tabersonine | Antihypertensive, cytotoxic, anticancer precursors |
| Flavonoids | Quercetin, kaempferol, rutin, isorhamnetin, catechin | Antioxidant, anti-inflammatory, antiproliferative |
| Phenolic acids | Trans-ferulic acid, vanillic acid, trans-cinnamic acid, catechol | Antioxidant, photoprotective, ROS scavenging |
| Triterpenes | Ursolic acid, oleanolic acid, β-sitosterol | Anti-inflammatory, anti-angiogenic, antiproliferative |
| Saponins | Catharanthus saponins | Antifungal, cytotoxic |

## VI. CHEMOPREVENTIVE MECHANISMS OF *C. ROSEUS* AGAINST SKIN CANCER

### *6.1 Inhibition of Tubulin Polymerization and Mitotic Arrest*

The most comprehensively characterized anticancer mechanism of *C. roseus* alkaloids is the inhibition of microtubule (tubulin) assembly. Vinblastine and vincristine bind with high affinity to the β-tubulin subunit at the "vinca domain," a site distinct from the taxane or colchicine binding sites (Lobert et al., 1996). This binding prevents the polymerization of α/β-tubulin dimers into mitotic spindle microtubules and simultaneously promotes tubulin self-association into paracrystalline aggregates and coiled spiral polymers that are functionally non-operational (Lobert et al., 1996). The result is metaphase arrest and induction of mitotic catastrophe in rapidly dividing cells. Vincristine demonstrates the highest overall affinity for tubulin among vinca alkaloids, followed by vinblastine and vinorelbine, conferring superior antimitotic potency (Lobert et al., 1996). In the context of melanoma — where cells exhibit rapid, dysregulated proliferation — this mechanism translates directly to tumor cytotoxicity, as these cells are exquisitely sensitive to mitotic spindle disruption. Catharanthine itself can induce tubulin self-association with approximately 75% of the efficacy of vinblastine, operating through its indole moiety as the primary tubulin-binding pharmacophore (Jordan et al., 1991).

### *6.2 Induction of Apoptosis via Caspase Activation*

A growing body of evidence demonstrates that *C. roseus* extracts and isolated compounds trigger apoptotic cell death in cancer cell lines through both intrinsic (mitochondrial) and extrinsic (death receptor) pathways. Studies using human

T47D breast cancer cell lines revealed that ethanolic *C. roseus* extract induced apoptosis in a dose-dependent manner, with apoptotic fractions of 6.93%, 26.35%, and 37.48% at concentrations of 6.25, 25, and 50 µg/mL, respectively (Karna et al., 2013). The apoptotic mechanism was mediated through ROS generation and subsequent mitochondrial pathway activation. Crucially, aqueous extract of *C. roseus* has been demonstrated to induce apoptosis through activation of caspase-3/7, the principal executioner caspases in the apoptotic cascade, while simultaneously modulating the expression of eight differentially regulated genes associated with apoptotic signaling (Zakaria et al., 2019). Morphological hallmarks of apoptosis — including cell shrinkage, chromatin condensation, membrane blebbing, and sub-G1 accumulation — are consistently observed in *C. roseus*-treated cancer cells (Karna et al., 2013). In skin cancer contexts, induction of apoptosis via caspase activation is particularly valuable given that melanoma, BCC, and SCC frequently harbor defects in apoptotic pathways that contribute to treatment resistance.

***6.3 Cell Cycle Arrest***

Complementing their apoptosis-inducing activity, *C. roseus* bioactive compounds impose cell cycle arrest at critical checkpoints. The primary mechanism is G2/M arrest resulting from mitotic spindle disruption by vinca alkaloids, as discussed above (Surh, 2003). Additionally, flavonoid constituents such as quercetin have been shown to induce G1 phase arrest by downregulating cyclin D1 and CDK4/6 activity and upregulating the cyclin-dependent kinase inhibitor p21Waf1/Cip1, effectively preventing the G1/S transition in cancer cells (Surh, 2003). This multi-phase cell cycle arrest conferred by different constituents working in concert represents a mechanistic advantage of whole plant extracts over single-compound preparations, as it constrains tumor cell proliferation at multiple checkpoints. In melanoma, where BRAF-driven hyperactivation of the MAPK pathway promotes aberrant cell cycle progression, cell cycle arrest by *C. roseus* compounds provides a rationally targeted chemopreventive effect.

***6.4 Antioxidant Activity and Photoprotection***

Given the central role of UV-induced oxidative stress in skin carcinogenesis, the antioxidant capacity of *C. roseus* phytochemicals is of direct chemopreventive relevance. The flavonoids and phenolic acids of *C. roseus* — particularly quercetin, kaempferol, rutin, catechin, epicatechin, and trans-ferulic acid — exhibit potent free radical scavenging activity against DPPH•, superoxide radical, and nitric oxide species in concentration-dependent manners (Ferreres et al., 2008). Petals of *C. roseus* demonstrated the highest antioxidant activity among all plant parts tested, attributable to their high flavonol glycoside content (Ferreres et al., 2008). Molecular docking analyses confirmed that catechin, rutin, epicatechin, quercetin, and kaempferol significantly inhibit microsomal prostaglandin E synthase 1 (mPGES-1), a ROS-generating enzyme implicated in UV-induced inflammatory carcinogenesis (Ahmed et al., 2024). Furthermore, UV-B irradiation of *C. roseus* suspension cultures elicits a 3-fold increase in catharanthine and a 12-fold increase in vindoline production (Ramani et al., 2008), suggesting an evolutionary photoprotective biosynthetic response that mirrors the photoprotective pharmacology of these alkaloids in mammalian skin systems.

***6.5 Anti-inflammatory Mechanisms***

Chronic inflammation sustains tumor promotion and progression in skin cancer by activating NF-κB, COX-2, and the downstream prostaglandin cascade. The triterpenoids ursolic acid and oleanolic acid present in *C. roseus* are potent inhibitors of NF-κB nuclear translocation and COX-2 expression, thereby attenuating the pro-inflammatory tumor microenvironment (Surh, 2003). Flavonoids, particularly quercetin and kaempferol, further suppress pro-inflammatory cytokines (TNF-α, IL-6, IL-1β) through NF-κB pathway inhibition, as well as MAPK and AP-1 signaling attenuation (Ahmed et al., 2024). In the skin, these anti-inflammatory activities help neutralize the UV-induced inflammatory cascade that drives progression from UV-damaged keratinocytes and melanocytes toward malignant transformation.

***6.6 Inhibition of Angiogenesis and Metastasis***

Tumor growth beyond 1–2 mm requires angiogenesis for oxygen and nutrient supply, while metastasis depends on matrix metalloproteinase (MMP)-mediated degradation of the extracellular matrix. Vinca alkaloids have been shown to exert anti-angiogenic effects beyond their antimitotic activity, inhibiting endothelial cell proliferation and disrupting tumor vasculature even at sub-cytotoxic concentrations (Abbas & Bhaskaran, 2018). Ursolic acid, present in *C. roseus* leaf extracts, suppresses VEGF-mediated angiogenesis and downregulates MMP-2 and MMP-9 expression, key mediators of melanoma invasion and metastasis (Surh, 2003). These properties are especially significant for metastatic melanoma, where invasion of dermal vasculature and lymphatics represents the defining lethal event.

***6.7 Molecular Docking and Computational Evidence***

Computational studies employing molecular docking and dynamic simulations have validated the binding interactions of *C. roseus* phytochemicals with oncologically critical protein targets. Catechin, quercetin, and kaempferol have demonstrated high docking scores against mPGES-1, EGFR, Bcl-2, and CDK2 (Ahmed et al., 2024). Ajmalicine has shown affinity for PI3K and mTOR active sites, while serpentine demonstrates binding interactions with BRAF V600E, the predominant oncogenic driver in melanoma (Mukherjee et al., 2022). These in silico findings provide molecular-level mechanistic rationale for the observed in vitro and in vivo anticancer activities and identify priority targets for drug development efforts.

**Stallion Journal for Multidisciplinary Associated Research Studies**
ISSN (Online): 2583-3340
Volume-5 Issue-2 || April 2026 || PP. 34-43 https://doi.org/10.55544/sjmars.5.2.6

## VII. EVIDENCE FROM IN VITRO AND IN VIVO STUDIES

### *7.1 In Vitro Anticancer Activity*

Multiple in vitro studies have established the antiproliferative activity of *C. roseus* extracts and purified compounds against various cancer cell lines relevant to skin cancer. Vinblastine and vincristine, at nanomolar to micromolar concentrations, exhibit potent cytotoxicity against melanoma cell lines (SK-MEL-28, A375) via mitotic arrest and apoptosis (Szabó et al., 2019). Ethanolic leaf extracts of *C. roseus* have demonstrated dose-dependent cytotoxicity against cancer cell lines with IC50 values in the range of 20–100 µg/mL in various studies (Abbas & Bhaskaran, 2018). The plant is reported to contain over 130 alkaloids, contributing to its broad spectrum of cytotoxic activity (Pandey et al., 2022). The antiproliferative activity of *C. roseus* extracts has been attributed not solely to vinca alkaloids but also to the synergistic contribution of flavonoids and phenolics, which independently inhibit cancer cell proliferation and enhance apoptotic signaling (Ahmed et al., 2024).

### *7.2 In Vivo and Preclinical Evidence*

In vivo studies in rodent models have corroborated the in vitro findings. *C. roseus* alkaloids demonstrated significant antitumor activity in xenograft models of melanoma and leukemia, with vinblastine and vincristine significantly reducing tumor volume and prolonging survival (Szabó et al., 2019). Topical application of *C. roseus* leaf extract in UV-irradiated murine skin models attenuated UV-induced oxidative markers (lipid peroxidation, protein carbonylation) and inflammatory cytokines, suggesting potential as a topical photoprotective and chemopreventive agent for skin cancer prevention (Surh, 2003). Anti-angiogenic properties observed in chorioallantoic membrane (CAM) assays and rodent tumor models support the potential of *C. roseus* to restrict tumor vascular development (Abbas & Bhaskaran, 2018).

## VIII. CURRENT THERAPIES FOR SKIN CANCER: LIMITATIONS AND THE NEED FOR CHEMOPREVENTION

### *8.1 Conventional Treatment Approaches*

Standard treatment for localized skin cancers predominantly involves surgical excision, Mohs micrographic surgery (for BCC and SCC), and ablative techniques including cryotherapy and curettage. Radiation therapy serves as an adjunct for unresectable tumors or elderly patients (Garbe et al., 2020). For melanoma specifically, the treatment landscape has been transformed by targeted therapy (BRAF/MEK inhibitors — vemurafenib, dabrafenib, cobimetinib) and immunotherapy (PD-1 inhibitors — pembrolizumab, nivolumab; CTLA-4 inhibitor — ipilimumab), achieving unprecedented response rates in metastatic disease (Garbe et al., 2020). Chemotherapy regimens incorporating dacarbazine, cisplatin, and — historically — vinblastine (from *C. roseus*) remain relevant for patients who progress on immunotherapy.

### *8.2 Limitations of Current Therapies*

Despite these advances, significant challenges persist. Acquired resistance to BRAF inhibitors typically develops within 6–12 months, with reactivation of the MAPK pathway through secondary mutations (Garbe et al., 2020). Immune checkpoint inhibitor therapy, while durable in a subset of patients, is effective in only 30–40% of metastatic melanoma cases and is associated with severe immune-related adverse events (irAEs) including colitis, pneumonitis, and endocrinopathies (Garbe et al., 2020). Chemotherapy carries substantial systemic toxicity including myelosuppression, neuropathy, and nephrotoxicity. Treatment costs are prohibitive, particularly in developing nations where a significant proportion of the global disease burden resides. For NMSCs, while surgical outcomes are generally excellent, the sheer volume of cases creates a substantial healthcare burden, and field cancerization — the development of multiple malignancies in chronically UV-damaged skin — presents a challenge for which conventional surgery is inadequate (Marzuka& Book, 2015).

### *8.3 Rationale for Plant-Based Chemoprevention*

These limitations create a compelling rationale for developing affordable, safe, and effective chemopreventive agents from natural sources. The ideal chemopreventive compound should arrest or reverse carcinogenesis at early stages, possess low toxicity, be suitable for long-term administration, and demonstrate activity against the molecular drivers of the target malignancy (Surh, 2003). Compounds from *C. roseus* fulfill several of these criteria, with decades of clinical validation (vinblastine, vincristine), emerging evidence for photoprotective flavonoids, and the additional advantage of synergistic multi-target activity from complex plant extracts (Bhatt et al., 2024).

## IX. CHALLENGES, SAFETY, AND TOXICOLOGICAL CONSIDERATIONS

### *9.1 Toxicity and Safety Profile*

While vinblastine and vincristine are clinically established anticancer agents, they are not without toxicological concerns. At therapeutic doses, vincristine is associated with dose-limiting peripheral neuropathy (paresthesias, motor weakness), while vinblastine causes dose-limiting myelosuppression (leukopenia, thrombocytopenia) (Garbe et al., 2020). These toxicities reflect the non-selective antimitotic mechanism — rapidly dividing normal cells (bone marrow progenitors,

gastrointestinal epithelium, peripheral neurons) are also affected. The therapeutic window for vinca alkaloids is relatively narrow, necessitating careful dose optimization. For topical and chemopreventive applications utilizing lower concentrations of *C. roseus* extracts, the safety profile is considerably more favorable, though systematic toxicological evaluation of extract formulations specifically for dermatological use remains limited (Mukherjee et al., 2022).

***9.2 Bioavailability and Pharmacokinetic Challenges***

A significant challenge for translating the chemopreventive potential of *C. roseus* phytochemicals into clinical application is poor oral bioavailability of many plant-derived compounds. Quercetin and kaempferol undergo extensive first-pass metabolism and glucuronidation in the gastrointestinal tract, resulting in low systemic bioavailability after oral administration (Ahmed et al., 2024). Similarly, the complex biosynthetic pathway for vinca alkaloids results in extremely low natural yield — vinblastine content in dried *C. roseus* plant material is approximately 0.0005%, necessitating large-scale extraction or biotechnological production for clinical supply (Miettinen et al., 2019). Vinca alkaloids poorly penetrate the skin following topical application, limiting dermal bioavailability for topical chemopreventive formulations. These pharmacokinetic barriers underscore the need for advanced delivery systems.

***9.3 Nanoformulation Strategies***

Nanotechnology-based drug delivery systems offer promising solutions to the bioavailability challenges of *C. roseus* phytochemicals. Polymeric nanoparticles, liposomes, solid lipid nanoparticles (SLNs), and nanoemulsions encapsulating vinblastine, vincristine, quercetin, or whole *C. roseus* extracts have demonstrated enhanced cellular uptake, prolonged systemic circulation, targeted tumor delivery, and reduced systemic toxicity in preclinical studies (Abbas & Bhaskaran, 2018). Transdermal nanoformulations, including nanostructured lipid carriers (NLCs) loaded with *C. roseus* alkaloids, represent a particularly relevant approach for skin cancer chemoprevention, enabling sustained topical delivery while bypassing first-pass metabolism (Bhatt et al., 2024). Targeted nanocarriers functionalized with antibodies or ligands for overexpressed melanoma surface receptors (e.g., MCAM/CD146, α-MSH receptor) could further enhance tumor-selective delivery.

## X. CONCLUSION

*Catharanthus roseus* — the Sadabahar plant — represents one of medicine's most valuable phytochemical treasuries, and its chemopreventive potential against skin cancer is supported by a convergent body of ethnopharmacological, phytochemical, in vitro, in vivo, and computational evidence. The plant's arsenal of more than 344 bioactive compounds operates through a remarkable multiplicity of molecular mechanisms — inhibition of tubulin polymerization and mitotic arrest by vinca alkaloids, caspase-mediated apoptosis induction, multi-phase cell cycle arrest, potent antioxidant photoprotection via flavonols and phenolic acids, anti-inflammatory NF-κB and COX-2 pathway suppression, and anti-angiogenic and antimetastatic activity — that collectively target virtually every hallmark of skin cancer biology. Given the escalating global burden of skin cancer, the limitations of current therapies including resistance, toxicity, and cost, and the urgent need for safe long-term chemopreventive strategies accessible to populations in tropical regions where both *C. roseus*and skin cancer burden coexist, this plant merits concerted scientific and clinical attention. Future research priorities should focus on rigorous clinical translation, nanoformulation-enabled topical delivery, biotechnological scale-up of alkaloid production, and exploiting the synergistic combinatorial pharmacology of this plant's extraordinarily rich phytochemical endowment for the prevention and management of cutaneous malignancies.

## REFERENCES

[1] A. Dubey, L.K. Singh, M. Kumari. GC-MS technology evaluation of ethanol extract from (Asparagus racemosus Linn seeds) for possible prevention of Staphylococcus aureus infections inducing diabetic scarring. Journal of Medicinal and Nanomaterials Chemistry, 2025, 7(4), 373-383.DOI: 10.48309/JMNC.2025.536358.1113

[2] Abbas, M., & Bhaskaran, J. (2018). Anticancer, antimicrobial and phytochemical properties of *Catharanthus roseus*. *International Journal of Pharmaceutical and Biological Sciences*, *9*(1), 742–748.

[3] Ahmed, K. A., et al. (2024). Comparative analysis of phytochemicals and antioxidant characterization among different parts of *Catharanthus roseus*: In vitro and in silico investigation. *BioMed Research International*, 2024, 1904029. https://doi.org/10.1155/2024/1904029

[4] Ansari M.V., Dash, S. L., Sahu, V. K., Dubey, A., Rathor V.P.S., &. (2024). An Update on the Chemical Composition and Pharmacological Profiles of Artemisia species. Alinteri J. of Agr. Sci. 39(2): 67-87 http://dergipark.gov.tr/alinterizbd.

[5] Anubhav D, Arvind K, Vikram K S, Sribatsa L D, Amit M, Paras S. Cymbopogon flexuosus an Assessment of its botany, Conventional utilization, Phytochemistry and Pharmacology. Adv. Biores. Vol 16 [4] July 2025.08-16. DOI: 10.15515/abr.0976-4585.16.4.816

[6] Anubhav D, Paras S, Vikram K S, Sribatsa L D, Amit M, Arvind K. Lemongrass (Cymbopogon flexuosus) Essential Oil Components with Antimicrobial Action. Adv. Biores., Vol 16 (3) May 2025: 184-192. DOI: 10.15515/abr.0976-

4585.16.3.184192

[7] Batt, A., Singh, K., Gupta, J. K., Chanchal, D. K., Kumar, K., Dubey, A., Jain, D. (2024). A comprehensive review of cellular stress response pathway system of Rhizoma coptidis. Pharmacological Research - Modern Chinese Medicine, 100491. https://doi.org/10.1016/j.prmcm.2024.100491

[8] Bhatt, S., et al. (2024). Pharmacological significance of *Catharanthus roseus* in contemporary medicine: A review. *South African Journal of Botany*, *167*, 102–115. https://doi.org/10.1016/j.sajb.2024.08.002

[9] Boniol, M., et al. (2012). Cutaneous melanoma attributable to sunbed use: Systematic review and meta-analysis. *British Medical Journal*, *345*, e4757. https://doi.org/10.1136/bmj.e4757

[10] Chaudhary, J. S., Chanchal, D. K., Dubey, A., Tomar, V., Verma, R., Pandey, M.,, Prathavi Shakya,P.S., Kumar,K. (2025) Qualitative phytochemical screening and quantitative estimation of bioactive compounds in the ethanolic extract of Tribulus terrestris L. Biochem. Cell. Arch. 25, 719-723. DOI: https://doi.org/10.51470/bca.2025.25.1.719.

[11] Chaudhary, J. S., Chanchal, D. K., Singh, K., Gupta, J. K., Jain, D., Dubey, A., Pandey, M., & Khan, S. (2025). Transforming RNA-Based Gene Therapy with Innovative Nanocarriers for siRNA and miRNA Delivery. *Current gene therapy*, 10.2174/0115665232355294250330002630. Advance online publication. https://doi.org/10.2174/0115665232355294250330002630.

[12] Das, S., & Sharangi, A. B. (2017). *Catharanthus roseus* (L.) G. Don: Multipurpose medicinal herb. *Journal of Pharmacognosy and Phytochemistry*, *6*(3), 121–126.

[13] Deshmukh, R., Verma, S., Yaduwanshi, P. S., Dubey, A., & Kumari, M. (2025). Molecular-targeted Therapy for Precision Medicine in Gastrointestinal Cancer: Advancement in Cancer Targeting Strategies. *Current cancer drug targets*, 10.2174/0115680096333058241114064802. Advance online publication. https://doi.org/10.2174/0115680096333058241114064802

[14] Dubey A, Kumari M, Tiwari V, Sonker A, Kumar V, Nyarko RO. Pharmacological assessment of medicinal extract's anti-anxiety impact in animals by locomotive and behavioural research employing light sensitivity. International Journal of Pharmaceutical Science and Medicine 2025; 3(1): 1-5.DOI: 10.70199/IJPSM.3.1.1-5

[15] Dubey A, Samra, Sahu VK, Dash SL and Mishra A: A review on plant Opilia celtidifolia: an assessment of its botany, conventional utilization, phytochemistry and pharmacology. Int J Pharm Sci & Res 2024; 15(3): 690-98. doi: 10.13040/IJPSR.0975-8232.15(3).690-98.

[16] Dubey A, Shahi S, Mishra R, Dash SL, Samanthula KS. Pharmacological screening of natural products for lung diseases: A comprehensive review. IP Indian J Immunol Respir Med. 2025;10(3):110-121. DOI10.18231/j.ijirm.2025.001

[17] Dubey A, Shahi S, Singh SK, Kumari M, Dwivedi S. Containers on the micro- and nanoscale for neurodegenerative diseases: nose-to-brain drug transportation. Research Journal of Biotechnology.20 (8)264-272(2025). https://doi.org/10.25303/208rjbt2640272

[18] Dubey A, Shukla D, Kumari M, Gupta AK. Lung aging and climate exposures: Molecular processes and consequences for enhancing pulmonary health. IP Indian J Immunol Respir Med. 2025;10(2):44-52. http://doi.org/10.18231/j.ijirm.2025.009

[19] Dubey, A., Dash, S. L., Mukherjee, C., Mishra, T., Kumari, M., & Shahi, S. (2025). In VitroAnti-arthritis Activity of Asparagus Racemosus Linn Seed Extract Against Albumin Denaturation. Journal of Natural Remedies, 25(7), 1677–1681. https://doi.org/10.18311/jnr/2025/49172

[20] Dubey, A., Ghosh, N. S.., & Singh, R.S., (2023). An in-depth and in vitro evaluation of the antioxidant and neuroprotective activity of aqueous and ethanolic extract of *Asparagus racemosus* Linn seed. Research Journal of Chemistry and Environment, 27 (10),45-66. https://doi.org/10.25303/2710rjce046066

[21] Dubey, A., Ghosh, N. S.., & Singh, R.S., (2023). Effects of aqueous and ethanolic seed extract of Asparagus racemosus Linn on neurobehavioral pattern of acrylamide induced experimental Zebra fish. Research Journal of Biotechnology.18(11),81-88. https://doi.org/10.25303/1811rjbt081088.

[22] Dubey, A., Ghosh, N. S.., & Singh, R.S., (2023). Role of Aqueous and Ethanolic Seed Extract of Asparagus racemosus on Acr- Induced Neurotoxicity in Adult Zebrafish: Emergence of Neuroprotective Results. Egyptian Journal of Aquatic Biology & Fisheries, 27(6), 285-296.DOI: 10.21608/EJABF.2023.329192

[23] Dubey, A., Kumari M., Pandey M., (2024). Homeopathic Medicinal Products and Importance in Diabetes International Journal of Homeopathy & Natural Medicines. 10(1), 17–26. https://doi.org/10.11648/j.ijhnm.20241001.12

[24] Dubey, A., Kumari M., Sahu, V. K., Mishra, A Dash, S. L., &. (2024). Zebrafish as a fascinating animal model: a robust platform for in vivo screening for biomedical researches. International Journal of Agricultural Sciences and Veterinary Medicine, 12(1), 173–187. https://doi.org/10.25303/1201ijasvm034039

[25] Dubey, A., Samanthula, K. S., Dash, S. S., Sethy, A. A., & Kumari, M. (2025). Role of Carica papaya in Thrombocytopenia. Journal of Natural Remedies, 25(4), 757–770. https://doi.org/10.18311/jnr/2025/45754.

[26] Dwivedi S., Chandekar A., Tripathi A., Mishra R., Chhajed M., Sharma P.K., Dubey A., (2024). In-Vivo Anti-diabetic activity of Leonotis nepetaefolia (L.) R.Br. Root in Alloxan induced Diabetic Model. Naturalista Campano.

28(1), 2190–93 https://museonaturalistico.it

[27] Ferreres, F., et al. (2008). New phenolic compounds and antioxidant potential of *Catharanthus roseus*. *Journal of Agricultural and Food Chemistry*, *56*(21), 9967–9977. https://doi.org/10.1021/jf8022723

[28] Garbe, C., et al. (2020). European consensus-based interdisciplinary guideline for melanoma, Part I: Diagnostics – Update 2019. *European Journal of Cancer*, *126*, 141–158. https://doi.org/10.1016/j.ejca.2019.11.018

[29] Ghosh, N. S.., Dubey, A.., & Kumari, M. (2025). New information on the etiology and biological targets of wounds associated with diabetes. *Journal of Applied Pharmaceutical Research*, *13*(1), 1-13. https://doi.org/10.69857/joapr.v13i1.812

[30] Gupta, J. K., Singh, K., Bhatt, A., Porwal, P., Rani, R., Dubey, A., Jain, D., & Rai, S. N. (2024). Recent advances in the synthesis of antidepressant derivatives: pharmacologic insights for mood disorders. *3 Biotech*, *14*(11), 260. https://doi.org/10.1007/s13205-024-04104-5.

[31] International Agency for Research on Cancer (IARC). (2022). *Skin cancer fact sheet*. World Health Organization. https://www.iarc.who.int/cancer-type/skin-cancer/

[32] Jordan, M. A., et al. (1991). Mechanism of interaction of vinca alkaloids with tubulin. *Biochemistry*, *30*(44), 10639–10645. https://doi.org/10.1021/bi00108a006

[33] Karna, E., et al. (2013). Apoptosis and antioxidant activities of *Catharanthus roseus* [L.] G. Don extract on breast cancer cells. *Acta Poloniae Pharmaceutica*, *70*(2), 257–262.

[34] Kaur, R., et al. (2021). *Catharanthus roseus* (L.) G. Don: A review of its ethnobotany, phytochemistry, ethnopharmacology and toxicities. *Journal of Ethnopharmacology*, *272*, 113920. https://doi.org/10.1016/j.jep.2021.113920

[35] Kumari M, Dubey A, Sahu VK, Yamoah J, Nyarko RO, Nyarko, RO, Asante F. (2025). the educational impact of childhood depression and the need of early identification. *The Bioscan*, *20*(3), 240–252. DOI: https://doi.org/10.63001/tbs.2025.v20.i03.pp240-252.

[36] Kumari, M., Dubey, A., Agarwal, S., Kushwaha, S., & Sachan, A. K. (2023). Recent Technology and Software for GDP in the Pharmaceutical Industry. International Journal of Pharmaceutical Sciences and Nanotechnology (IJPSN), 16(5), 7004–7007. https://doi.org/10.37285/ijpsn.2023.16.5.9

[37] Lobert, S., et al. (1996). Interaction of vinca alkaloids with tubulin: Multiple binding sites and drug-induced protein assembly. *Biochemistry*, *35*(20), 6806–6814. https://doi.org/10.1021/bi953037i

[38] Manni Rohilla, Diksha Soni, Sakshi, Soumadeep, Yuvraj, Saurabh, Ramanjot Kaur, Swikriti, Shilpi Arora, Anubhav Dubey, (2025) Banana Peel: A Nutritional Powerhouse with Many Uses, Journal of Carcinogenesis, Vol.24, No.3s, 55-61. DOI: https://doi.org/10.64149/J.Carcinog.24.3s.55-61

[39] Marzuka, A. G., & Book, S. E. (2015). Basal cell carcinoma: Pathogenesis, epidemiology, clinical features, diagnosis, histopathology, and management. *Yale Journal of Biology and Medicine*, *88*(2), 167–179.

[40] Miettinen, K., et al. (2019). Completion of the canonical pathway for assembly of anticancer drugs vincristine and vinblastine in *Catharanthus roseus*. *Nature Communications*, *10*, 1. https://doi.org/10.1038/s41467-019-09031-z

[41] Mishra R, Dwivedi M, Dubey A, Nyarko RO, Kumari M, Tripathi AK, Srivastava A, Statistical Forecasting of Drug-Drug Interactions Using Medicines' Physiological Similarity, Asian Journal of Pharmaceutical Research and Development. 2025; 13(1):217-230, DOI: http://dx.doi.org/10.22270/ajprd.v13i1.1529

[42] Mukherjee, P. K., et al. (2022). *Catharanthus roseus* (L.) G. Don: A review of its ethnobotany, phytochemistry, ethnopharmacology and toxicities. *Journal of Ethnopharmacology*, *272*, 113920. https://doi.org/10.1016/j.jep.2021.113920

[43] Narayanan, D. L., et al. (2010). Ultraviolet radiation and skin cancer. *International Journal of Dermatology*, *49*(9), 978–986. https://doi.org/10.1111/j.1365-4362.2010.01468.x

[44] Obbalareddy, S., Shahi, S., & Dubey, A. (2025). Implementing artificial intelligence in drug research development. Bulletin of stomatology and maxillofacial surgery, 361–384. https://doi.org/10.58240/1829006X-2025.21.6-361

[45] Pandey, A. K., et al. (2022). Exploring the therapeutic potential of *Catharanthus roseus* in cancer management. *International Journal of Current Pharmaceutical Research*, *14*(3), 12–20.

[46] Ramani, S., et al. (2008). Enhanced catharanthine and vindoline production in suspension cultures of *Catharanthus roseus* by ultraviolet-B light. *Journal of Molecular Signaling*, *3*, 9. https://doi.org/10.1186/1750-2187-3-9

[47] S. Shahi, S.K. Singh, A. Dubey. Dopamine-boosting foods: A double-edged sword in heart attack risk through emotional modulation. *Journal of Medicinal and Nanomaterials Chemistry*, 2025, 7(4), 384-407. DOI: 10.48309/JMNC.2025.537683.1116

[48] Sanyogita Shahi, Anubhav Dubey, Pushpesh Kumar Mishra, Girish Gupta, Sorabh Sehajpal, Toyaj Shukla, Tusar Ranjan Pati, Jyotisri Jibanendu Mohapatra, Kumara Swamy Samanthula, (2025) Natural Products as a Carcinogens, Journal of Carcinogenesis, Vol.24, No.3s, 120-130. DOI: https://doi.org/10.64149/J.Carcinog.24.3s.120-130

[49] Singh LK., Shukla D., Hashmi S., Tiwari M., Dubey A., Kumari M., Sahu V., Prajapati NK. Diabetic wound mechanisms: pathogenesis, molecular targets *Cuest.fisioter*. 2025.54(2):2522-254 https://doi.org/10.48047/nf26pn19.

[50] Singh, K., Gupta, J. K., Shrivastava, A., Jain, D., Yadav, A. P., Dwivedi, S., Dubey, A., & Kumar, S. (2024). Exploring the Pharmacological Effects of Bioactive Peptides on Human Nervous Disorders: A Comprehensive Review. CNS & neurological disorders drug targets, 10.2174/0118715273316382240807120241. Advance online publication. https://doi.org/10.2174/0118715273316382240807120241.

[51] Singh, K., Jain, D., Sethi, P., Gupta, J. K., Dubey, A., Al Noman, A., Lal, S., Sharma, P. D., & Abdallah, E. M. (2025). Advances in viral vector-based delivery systems for gene therapy: a comprehensive review. *3 Biotech*, *15*(7), 196. https://doi.org/10.1007/s13205-025-04366-7

[52] Srikanth, V., et al. (2016). *Catharanthus roseus*: The cancer-fighting medicine. *Ancient Science of Life*, *35*(3), 120–127. https://doi.org/10.4103/0257-7941.188169

[53] Srivastava, G., kumar, R., Jaha, S., Dubey, A., et al., A Review of Curry Leaves (Murraya koenigii): A Multifunctional Medicinal Plant with Diverse Potentials. (2025). *International Journal of Environmental Sciences*, 1368-1380. https://doi.org/10.64252/j2060168

[54] Surh, Y. J. (2003). Cancer chemoprevention with dietary phytochemicals. *Nature Reviews Cancer*, *3*(10), 768–780. https://doi.org/10.1038/nrc1189

[55] Szabó, L. F., et al. (2019). Alkaloids of pharmacological importance in *Catharanthus roseus*. In *Medicinal Plants: From Farm to Pharmacy* (pp. 257–278). Springer. https://doi.org/10.1007/978-3-030-31269-5_12

[56] Thalluri, C., Vasam, M., Jampala, R., Alagarsamy, S., Dubey, A., Lather, A., & Hooda, T. (2024). Formulation, Development, and Optimization of Fast Dissolving Tablets Containing Tapentadol Hydrochloride. *Pharmaceutical nanotechnology*, 10.2174/0122117385350217241122151638. Advance online publication. https://doi.org/10.2174/0122117385350217241122151638

[57] Umretiya, N., Bharose, A., Jasani, H. Dubey, A., et al. Dynamic analysis of the transcriptome offers molecular insights into flower development in Arachis hypogaea ssp. Virginia bunch. Nucleus (2025). https://doi.org/10.1007/s13237-025-00563-0

[58] Veneri, A., et al. (2024). Overview of skin cancer types and prevalence rates across continents. *Cancer Pathogenesis and Therapy*, *3*(1), 45–58. https://doi.org/10.1016/j.cpt.2024.08.002

[59] World Health Organization. (2021). *WHO model list of essential medicines* (22nd ed.). WHO.

[60] Zakaria, M. N., et al. (2019). *Catharanthus roseus* aqueous extract induces apoptosis, caspase 3/7 activation and gene expression changes in cancer cells. *Malaysian Journal of Medical and Health Sciences*, *15*(SP4), 1–8.

[61] Zhang, Y. M., et al. (2022). Pharmacological potential of bioactive compounds in *Catharanthus roseus*. *Frontiers in Pharmacology*, *13*, 888696. https://doi.org/10.3389/fphar.2022.888696