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UNLOCKING NATURE'S POWER: A DECADE OF MEDICINAL PLANTS REVOLUTIONIZING CANCER THERAPY

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Medicinal plants, Anticancer activity, Phytochemicals, Apoptosis, Cancer therapy, Natural products

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ABSTRACT: Cancer is a severe global health burden, responsible for significant morbidity and mortality globally. Despite breakthroughs in traditional therapies including chemotherapy, radiation, and surgery, these methods are frequently associated with side effects, drug resistance, and limited selectivity. In recent years, medicinal plants have received increased interest as a source of bioactive chemicals with potential anticancer properties. The current analysis conducts a comprehensive evaluation of medicinal plants published between 2014 and 2024 for their anticancer potential. A structured literature search was carried out utilizing major databases, with papers chosen based on established inclusion and exclusion criteria. The review focuses on the mechanisms of action, level of evidence, and translational significance of plant-derived chemicals. The findings suggest that a wide range of medicinal plants have anticancer action via mechanisms such as apoptosis induction, cell growth suppression, signalling pathway modification, and antioxidant properties. However, the bulk of studies focus on *in-vitro* and preclinical models, with only a few well-designed clinical trials. In conclusion, while medicinal plants represent a promising alternative approach in cancer therapy, further study is needed to address issues of standardization, safety, and clinical validation.

INTRODUCTION: Cancer is one of the leading causes of sickness and death globally, and it is a major public health issue compounded by population growth, age, and lifestyle changes. In 2026, it is anticipated that over 2.1 million new cancer cases would be diagnosed in the United States alone, with over 626,000 fatalities [2]. Although traditional therapy approaches have improved patient outcomes, with a historic 70% five-year survival rate for all malignancies combined, they are typically accompanied by significant limits like as systemic toxicity and the development of multidrug resistance.

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As a result, there is an increasing interest in natural goods, particularly medicinal herbs, which have been used for millennia and contain bioactive compounds [5, 41]. Phytochemicals such as alkaloids, flavonoids, terpenoids, and phenolic compounds have a variety of pharmacological effects, including anti-inflammatory and anti-proliferative activities [33, 34].

Several plant-derived compounds, such as paclitaxel and vincristine, have been effectively incorporated into modern oncology, although clinical translation of newer candidates remains restricted. Significant challenges remain, including extraction procedure standardization, toxicity assessment, pharmacokinetics, and regulatory approval [46, 49]. This study aims to objectively evaluate medicinal plants described in the last decade, with a focus on their mechanisms of action and translational potential.

Review Methodology: This review was planned and methodical in order to provide a full and unbiased assessment of medicinal plants having anticancer effects. A complete literature search was carried out using electronic databases such as PubMed, Scopus, Web of Science, and Google Scholar. The search method combined phrases such as "medicinal plants," "anticancer activity," "phytochemicals," "natural products in cancer therapy," and "herbal medicine oncology" using Boolean operators. To meet the journal's criteria for current relevance, the review focused on publications published during the recent decade (2016-2026). Inclusion criteria included experimental research demonstrating anticancer activity *in-vitro*, *in-vivo*, or in clinical settings, as well as studies examining the molecular processes of plant-derived compounds. Research with insufficient methodological information, non-English publications, and papers that predate the given time range were removed. Data were collected and analyzed based on plant species, active compounds, cancer type, experimental model, and anticipated mechanisms of action to establish a key analytical framework rather than just a descriptive one.

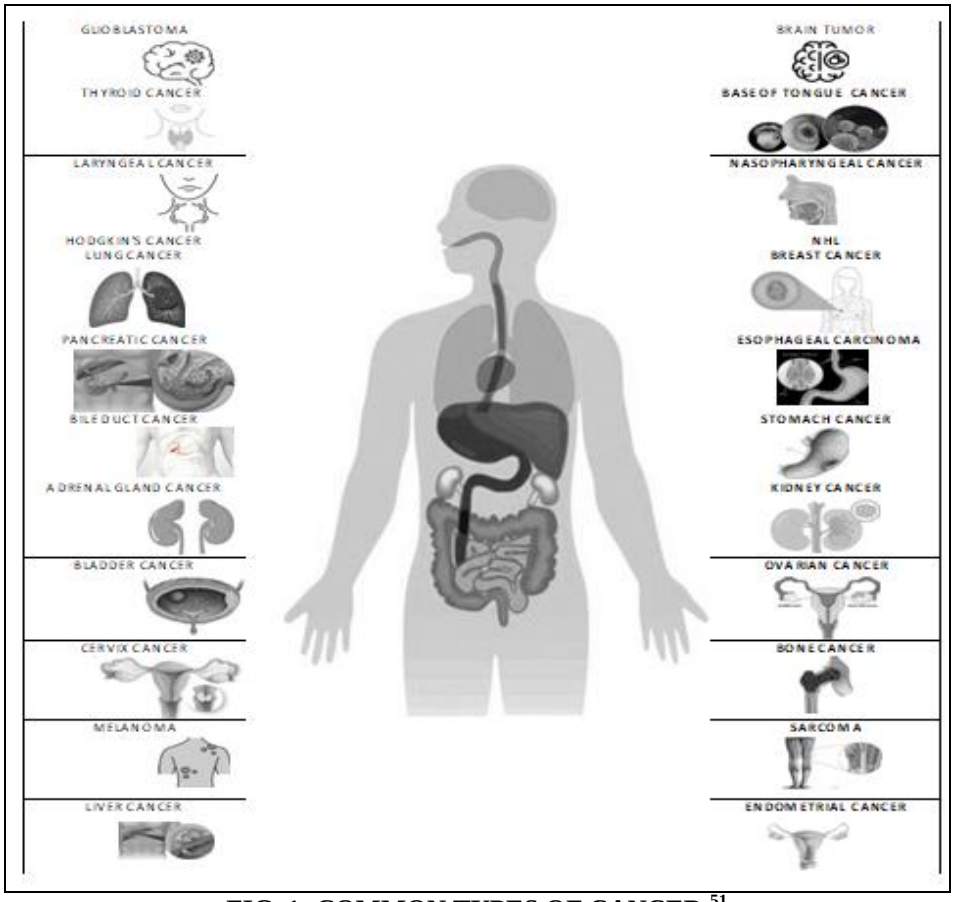

FIG. 1: COMMON TYPES OF CANCER [51]

General Mechanisms of Anticancer Action: Herbal remedies have anticancer effects through a number of molecular and cellular mechanisms [20, 31]. One of the key techniques is to induce apoptosis, which is a programmed cell death process that eliminates faulty cells through both intrinsic and extrinsic mechanisms including mitochondrial dysfunction and caspase activation [6, 32]. Another important mechanism is the generation of reactive oxygen species (ROS), which induces oxidative stress and selective cytotoxicity in cancer cells [7, 27]. Furthermore, plant-derived compounds can inhibit tumor cell growth by arresting the cell cycle at certain checkpoints, such as the G1/S or G2/M stages [9, 34]. Phytochemicals alter signalling pathways such as MAPK, EGFR, VEGF, Ras/Raf, and NF-κB, affecting cell survival, angiogenesis, and metastasis [8, 16]. Some chemicals, such as those found in pomegranate and green tea have anti-angiogenic and anti-metastatic properties, which inhibit tumor development and spread [11, 33].

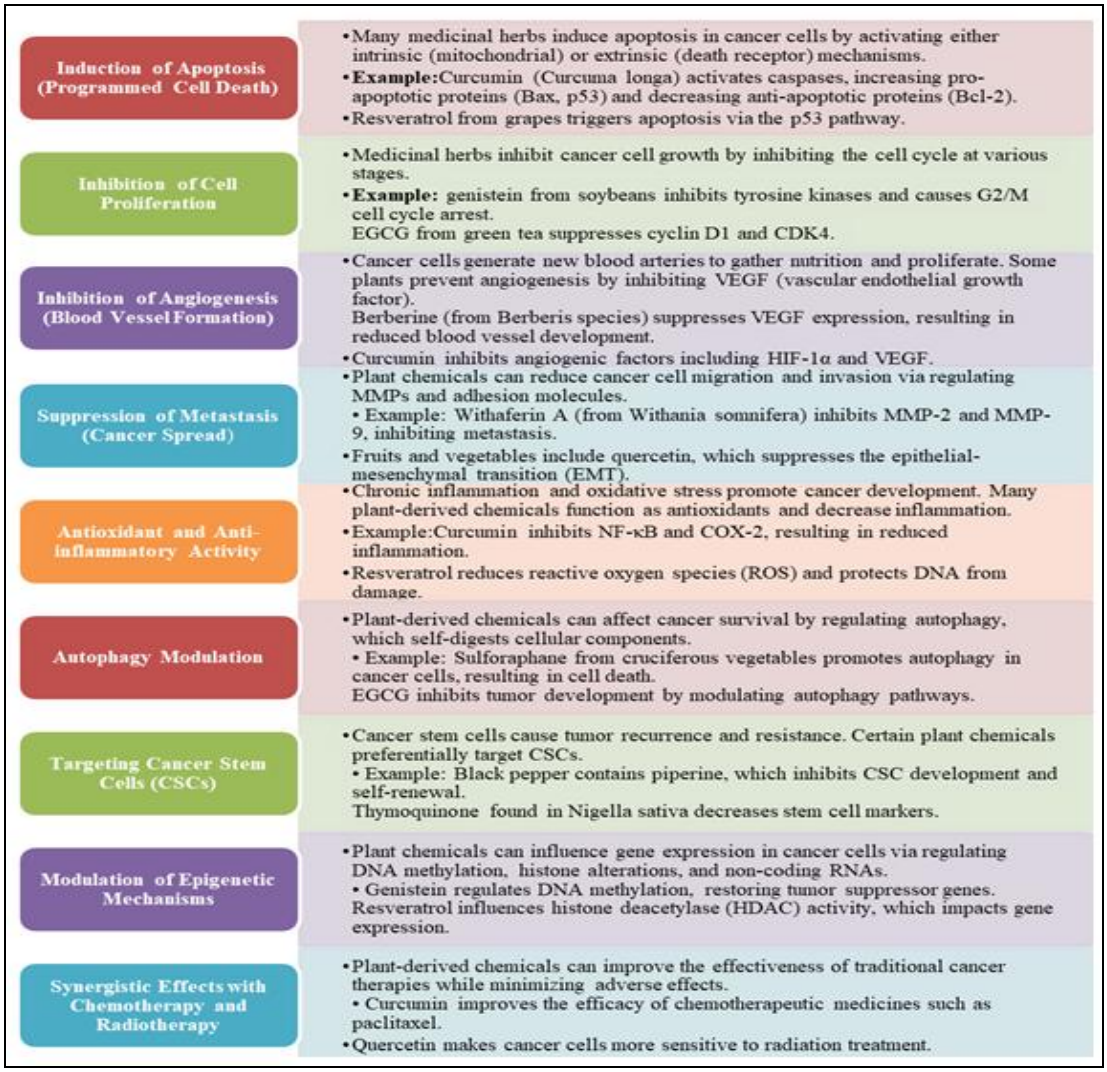

FIG. 2: GENERAL MECHANISM OF ACTIONS OF HERBAL PLANTS POSSESSING ANTICANCER ACTIVITY

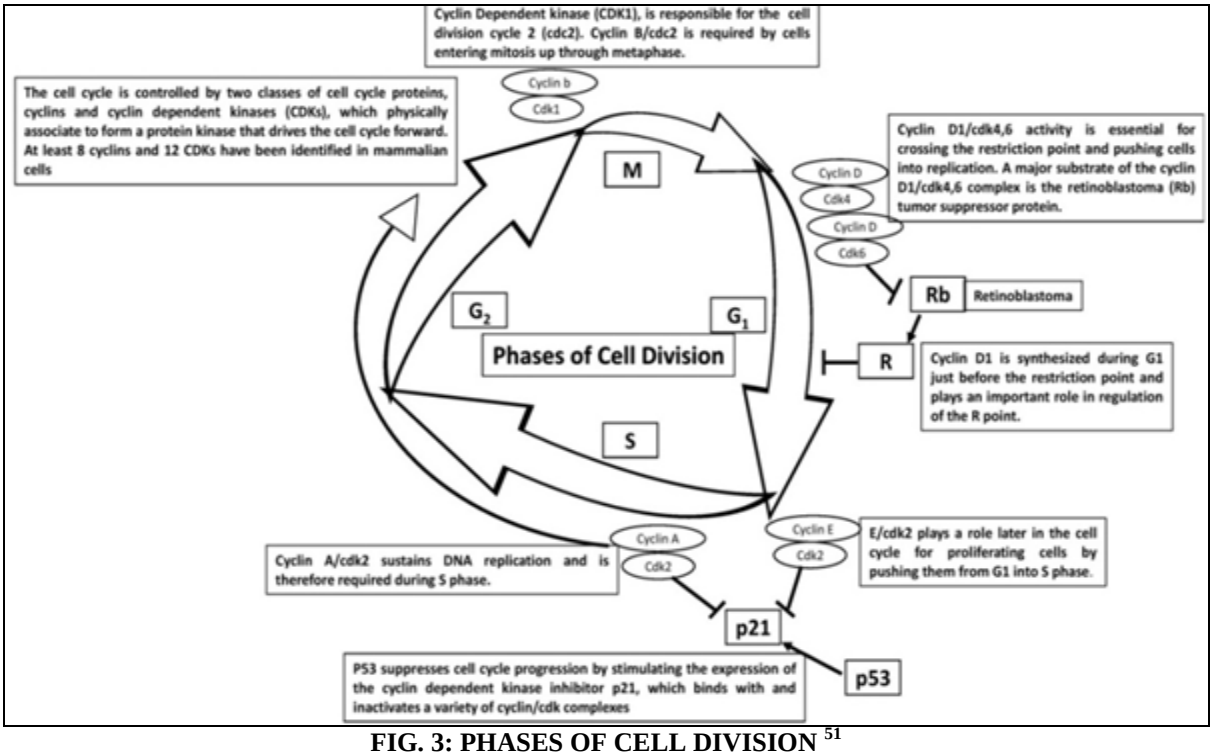

FIG. 3: PHASES OF CELL DIVISION [51]

Advantages and Limitations of Herbal Drugs: Medicinal herbs have various advantages as possible anticancer medicines because of their natural origin and multi-targeted mechanisms of action. They are widely available and have long been used in a variety of medical systems. Certain phytochemicals have demonstrated a favorable safety profile in preclinical models and may mitigate the systemic toxicity of conventional chemotherapeutics when used in synergistic combinations. However, clinical safety remains contingent upon rigorous standardization of dosage and extraction protocols [3, 31, 34]. However, these advantages should be viewed with caution. The safety and efficacy of herbal medications are greatly reliant on dosage, extraction processes, and formulation. Lack of standardization frequently leads to variability in active ingredients, which can impair repeatability and therapeutic outcomes [46]. Furthermore, inadequate clinical validation and insufficient data on pharmacokinetics and toxicity pose considerable barriers to their clinical implementation [42, 50]. So, therefore, medicinal plants should be considered as complementary approaches as complementary approaches rather than direct replacements for current medications until robust and well-controlled clinical evidence is forthcoming [41].

Scientific Classification of Selected Medicinal Plants:

TABLE 1: SCIENTIFIC/TAXONOMICAL CLASSIFICATION OF SELECTED MEDICINAL PLANTS

S. no.	Scientific Name (Italic)	Family	Common Name	Part Used	Reference
1	*Bauhinia racemosa* Lam.	Fabaceae	Bidi leaf tree	Leaves	[11]
2	*Abutilon indicum* (L.) Sweet	Malvaceae	Indian mallow	Leaves	[12]
3	*Aglaia roxburghiana* Miq.	Meliaceae	Aglaia	Leaves	[13]
4	*Cocculus hirsutus* (L.) Diels	Menispermaceae	Broom creeper	Leaves	[17]
5	*Hyptis suaveolens* (L.) Poit.	Lamiaceae	Bush mint	Leaves	[22]
6	*Tetrastigma serrulatum* Planch.	Vitaceae	Wild grape	Leaves	[27]
7	*Thespesia populnea* (L.) Sol. ex Corrêa	Malvaceae	Portia tree	Leaves	[28]
8	*Ajuga bracteosa* Wall. ex Benth.	Lamiaceae	Bugleweed	Whole plant	[14]
9	*Coix lacryma-jobi* L.	Poaceae	Job's tears	Seeds	[18]
10	*Luffa cylindrica* (L.) M. Roem.	Cucurbitaceae	Sponge gourd	Fruit	[23]
11	*Caesalpinia pulcherrima* (L.) Sw.	Fabaceae	Peacock flower	Leaves	[15]
12	*Semecarpus anacardium* L. f.	Anacardiaceae	Marking nut	Nuts	[25]
13	*Symplocos racemosa* Roxb.	Symplocaceae	Lodhra	Bark	[26]
14	*Rhus succedanea* L.	Anacardiaceae	Wax tree	Leaves	[24]
15	*Camellia sinensis* (L.) Kuntze	Theaceae	Green tea	Leaves	[16]
16	*Crocus sativus* L.	Iridaceae	Saffron	Stigma	[20]
17	*Azadirachta indica* A. Juss.	Meliaceae	Neem	Leaves	[3]
18	*Curcuma longa* L.	Zingiberaceae	Turmeric	Rhizome	[29]

Medicinal Plants with Anticancer Activity: A wide variety of medicinal plants have been evaluated for their anticancer properties. To reduce redundancy and improve analytical clarity, these plants can be classified according to their primary modes of action and amount of scientific proof.

Plants Inducing Apoptosis *via* Oxidative Stress: A substantial amount of medicinal plants exhibit anticancer action by inducing oxidative stress and apoptosis. *Bauhinia racemosa*, *Abutilon indicum*, and *Aglaia roxburghiana* have been shown to have strong cytotoxic effects on a variety of cancer cell lines, principally through enhanced reactive oxygen species (ROS) formation and mitochondrial-mediated apoptosis [11-13]. Similarly, *Cocculus hirsutus*, *Hyptis suaveolens*, *Tetrastigma serrulatum*, and *Thespesia populnea* have antiproliferative properties linked to oxidative stress-mediated pathways [17, 22, 27, 28]. Furthermore, widely studied medicinal plants such as *Azadirachta indica* and *Curcuma longa* have demonstrated significant anticancer activity via apoptosis induction and regulation of important intracellular signaling pathways [3, 29].

However, it is important to emphasize that the majority of these findings are based on *in-vitro* experimental models, with little validation *in-vivo* or clinical research. Further research is needed to determine the translational significance and therapeutic application of these plant-derived chemicals in cancer treatment [41].

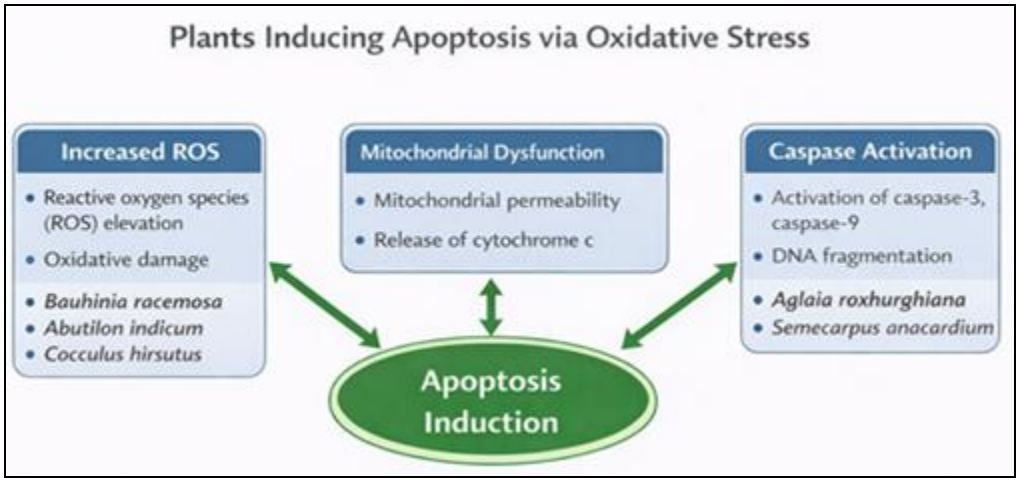

FIG. 4: COMPILED MODE OF ACTION OF SELECTED MEDICINAL PLANTS INDUCING APOPTOSIS *VIA* OXIDATIVE STRESS

Plants Targeting Cell Cycle Regulation and Proliferation: Several herbs for medicinal purposes slow cancer growth by disrupting cell cycle control and decreasing tumor cell proliferation. *Ajuga bracteosa*, *Coix lacryma-jobi*, and *Luffa cylindrica* have been shown to stop cell cycle progression and reduce proliferation in several cancer cell lines [14, 18, 23]. Furthermore, *Withania somnifera* and *Tinospora cordifolia* have strong antiproliferative effect by modulating cyclins, cyclin-dependent kinases (CDKs), and tumor suppressor proteins, which regulate important checkpoints in the cell cycle [31, 33]. These plants are also said to have immunomodulatory capabilities, which may add to their overall anticancer potential [34]. However, the majority of these findings come from preclinical studies, and there is little clinical evidence to substantiate their therapeutic efficacy. Therefore, more well-designed *in-vivo* and clinical investigations are required to validate these findings.

Plants with *In-vivo* Anticancer Evidence: Compared to *in-vitro* research, some medicinal plants have shown anticancer action in animal models, offering stronger evidence for their therapeutic potential. *Caesalpinia pulcherrima* and *Semecarpus anacardium* have been found in experimental models to inhibit tumors and improve survival rates [15, 25]. Similarly, *Symplocos racemosa* and *Rhus succedanea* have anticancer properties mediated by antioxidant activity and apoptotic induction [26, 24]. Furthermore, *Catharanthus roseus*, a well-known source of anticancer alkaloids like vincristine and vinblastine, is a successful example of plant-derived drug research with clinical applications [3, 39]. Although these findings are encouraging, most research is limited to preclinical models. Therefore, additional well-designed clinical studies are required to establish the safety, efficacy, and therapeutic relevance of these plant-derived medicines in human cancer treatment [41].

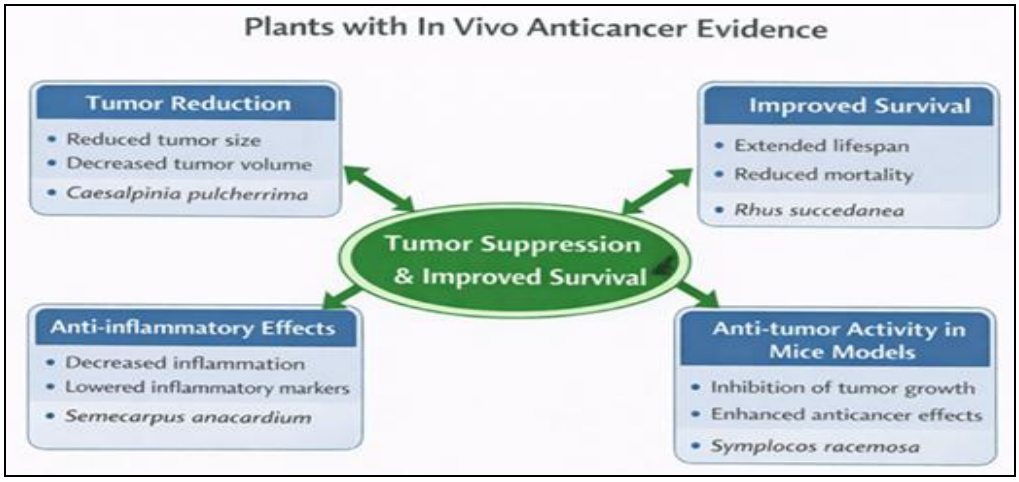

FIG. 5: COMPILED MODE OF ACTION OF SELECTED MEDICINAL PLANTS WITH *IN-VIVO* EVIDENCE

Plants with Clinical or Translational Evidence: Only a few medicinal plants investigated have shown significant clinical or translational relevance. *Camellia sinensis* (green tea) has been widely studied, and its bioactive constituent epigallocatechin gallate (EGCG) demonstrates antioxidant, anti-angiogenic, and antiproliferative properties across several cancer models [16, 32]. Similarly, *Crocus sativus* (saffron) has shown promising anticancer activity, with compounds like crocin showing efficacy in both experimental models and limited clinical studies [20]. Furthermore, *Taxus brevifolia*, the source of paclitaxel, and *Podophyllum hexandrum*, the source of podophyllotoxin derivatives, are well-known instances of effective translation of plant-derived compounds into therapeutically useful anticancer medicines [3, 39].

Despite these developments, the number of well-designed, large-scale clinical trials assessing plant-derived anticancer medicines is still low. As a result, additional thorough clinical studies are required to prove their safety, effectiveness, and therapeutic relevance in oncology treatment [41].

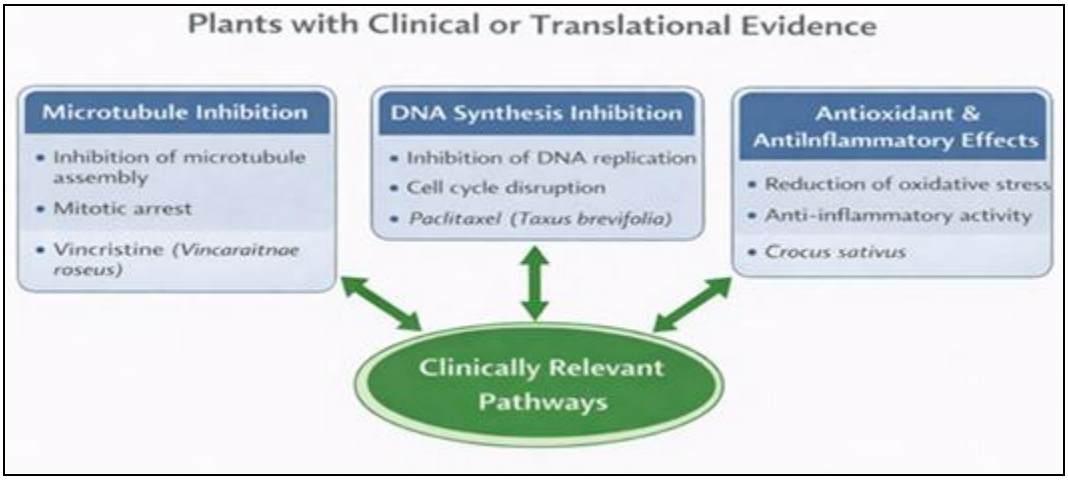

FIG. 6: COMPILED MODE OF ACTION OF CLINICALLY RELEVANT PATHWAYS IN PLANT-DERIVED MEDICINES

TABLE 2: ANTICANCER ACTIVITY OF SELECTED MEDICINAL PLANTS WITH MECHANISM AND LEVEL OF EVIDENCE

S. no.	Plant Name	Family	Major Active Constituents	Cancer Type / Model	Key Mechanism	Evidence Level	Ref.
1	*Bauhinia racemosa*	Fabaceae	Flavonoids, tannins, β-sitosterol	Cervical, MCF-7, HepG2	ROS-mediated apoptosis	*In-vitro*	[11]
2	*Abutilon indicum*	Malvaceae	Alkaloids, flavonoids, glycosides	Lung, breast cancer cells	Antiproliferative activity	*In-vitro*	[12]
3	*Aglaia roxburghiana*	Meliaceae	Sesquiterpenoids, triterpenoids	HepG2, MCF-7	Cytotoxicity, apoptosis	*In-vitro*	[13]
4	*Ajuga bracteosa*	Lamiaceae	Terpenoids, flavonoids	Liver, lung, breast cancer	Cell cycle arrest, tumor inhibition	*In-vitro / In-vivo*	[14]
5	*Caesalpinia pulcherrima*	Fabaceae	Flavonoids, tannins	Breast cancer (MCF-7)	Cytotoxic, apoptosis	*In-vitro*	[15]
6	*Camellia sinensis*	Theaceae	Catechins (EGCG), flavonoids	Lung, breast, prostate	Anti-angiogenic, antiproliferative	*In-vitro /* Clinical	[16]
7	*Cocculus hirsutus*	Menispermaceae	Alkaloids, glycosides	Multiple cancer cell lines	Cytotoxic activity	*In-vitro*	[17]
8	*Coix lacryma-jobi*	Poaceae	Coixenolide, polyphenols	Lung, colon cancer	Cell growth inhibition	*In-vitro / In-vivo*	[18]
9	*Corchorus aestuans*	Malvaceae	β-sitosterol, cardenolides	Breast, colon, liver cancer	Cytotoxic, metabolic modulation	*In-vitro*	[19]
10	*Crocus sativus*	Iridaceae	Crocin, terpenes	Breast, ovarian, liver	Anti-metastatic, apoptosis	*In-vivo /* Clinical	[20]
11	*Heliotropium indicum*	Boraginaceae	Pyrrolizidine alkaloids	Breast, cervical cancer	Cytotoxic activity	*In-vitro*	[21]
12	*Hyptis*	Lamiaceae	Terpenoids, cineole	Breast, colorectal	Antiproliferative	*In-vitro*	[22]

	suaveolens			cancer			
13	*Luffa cylindrica*	Cucurbitaceae	Flavonoids, triterpenes	Breast, colon cancer	Cytotoxic, apoptosis	*In-vitro*	[23]
14	*Rhus succedanea*	Anacardiaceae	Fisetin, tannins	Lung, breast, colon	Antioxidant, apoptosis	*In-vitro*	[24]
15	*Semecarpus anacardium*	Anacardiaceae	Polyphenols, flavonoids	Leukemia, breast cancer	Cytotoxic, apoptosis	*In-vitro / In-vivo*	[25]
16	*Symplocos racemosa*	Symplocaceae	Triterpenoids, lignans	Ovarian, breast cancer	Cytotoxic, anti-inflammatory	*In-vitro*	[26]
17	*Tetrastigma serrulatum*	Vitaceae	Flavonoids, alkaloids	Liver, breast, leukemia	Antiproliferative	*In-vitro*	[27]
18	*Thespesia populnea*	Malvaceae	Gossypol, flavonoids	Liver, breast cancer	Cytotoxic, anti-inflammatory	*In-vitro*	[28]

Challenges and Future Perspectives: The clinical development of plant-derived anticancer medicines poses major pharmacological and regulatory challenges. One major difficulty is a lack of phytochemical consistency; variances caused by geographical and extraction variables result in unpredictable therapeutic effects and impede standardized dosage. Furthermore, many powerful phytochemicals have poor pharmacokinetic characteristics, including limited water solubility and fast systemic clearance, leading to inadequate bioavailability.

Scientific care is essential when it comes to safety; the notion of intrinsic safety is called into question by dangers of systemic toxicity and negative drug-herb interactions. Current research is largely focused on exploratory in vitro data, emphasizing the importance of high-quality *in-vivo* investigations and multicenter clinical trials. Future research should focus on nanotechnology-based delivery methods that improve the stability and target specificity of plant-derived medicines. Such methodical development is required for regulatory clearance and effective validation of natural compounds as oncology treatments.

CONCLUSION: Medicinal plants encompass a large number of bioactive metabolites that have been shown to have strong antineoplastic activity in a variety of experimental settings. Evidence gathered over the last decade suggests that these phytochemicals influence fundamental molecular drivers of carcinogenesis, such as the induction of programmed cell death (apoptosis), the suppression of abnormal cell proliferation, and the attenuation of dysregulated intracellular signaling cascades. However, a comprehensive examination of the present literature indicates that the great majority of existing evidence is generated from *in-vitro* and preclinical models, with a continued lack of well-validated, large-scale clinical studies to support definite therapeutic uses in human cancer.

Despite major advances in pharmacotechnical techniques, particularly the creation of nanotechnology-based delivery systems and the investigation of synergistic combination regimens with traditional chemotherapeutics, significant impediments to clinical translation remain. Critical issues include a lack of substantial phytochemical standardization, variations in dose across various extracts, poor pharmacokinetic profiles, and the need for more complete safety and toxicity studies. Furthermore, negotiating the complicated environment of regulatory approval remains a considerable barrier to the incorporation of these medications into routine clinical practice.

As a result, future research efforts must emphasize the design of robust clinical trials, the development of uniform extraction and formulation processes, and the implementation of detailed mechanistic validation at the molecular and genomic levels. Establishing the definitive therapeutic value of medicinal plants in cancer requires a multidisciplinary, evidence-based approach that successfully blends ethnomedicinal knowledge with modern molecular biology and clinical research. In conclusion, while botanical agents show great promise as cancer treatment adjuncts, their successful incorporation into clinical oncology necessitates rigorous scientific validation, methodical developmental protocols, and a shift from exploratory observations to standardized clinical evidence.

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