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ANTICANCEROUS POTENTIAL OF MEDICINAL PLANTS- A REVIEW

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ABSTRACT

Cancer is a major public health burden in both developed and developing countries and globally the numbers of cancer patients are increasing day by day. There are several medicines available in the market to treat the various types of cancer but no drug is found to be fully effective and safe. So the anticancer activity of certain natural products and their analogs are being explored. Diverse efficient compounds derived from natural products have been isolated as anticancer agents. These chemical compounds are formulated with a view to create effective drugs against cancer. This review focuses on some medicinal plants used for treating cancer. The phytochemical exploration of these plants will make significant contribution to the discovery of new anticancer drugs. In recent years, owing to the fear of side effects, people prefer to use natural plant products for cancer treatment. Although drug discovery from medicinal plants continues to provide an important source of safe drugs, numerous challenges are encountered including the procurement of plant materials and their selection. This paper reviews wide array of promising bioactive compounds obtained from various medicinal plants and their potential therapeutic uses.

KEYWORDS: Cancer, Bioactive compounds, Medicinal plants, Anti-cancerous property.

INTRODUCTION

Medicinal plants have been used for the treatment of various diseases for thousands of years. Among the human diseases treated with medicinal plants, cancer is probably the most important genetic disease. Every year, millions of people are diagnosed with cancer, leading

to death in a majority of the cases. Many of the claims for efficacy in the treatment of cancer, however, should be viewed with some skepticism because cancer, as a specific disease entity, is likely to be poorly defined in terms of folklore and traditional medicine. This is in contrast to other plant-based therapies used in traditional medicine for the treatment of afflictions such as malaria and pain, which are more easily defined, and where the diseases are often prevalent in the regions where traditional medicine systems are extensively used. However, despite these observations, it is significant that over 60% of currently used anti-cancer agents are derived in one way or another from natural sources, including plants. Chemotherapy, being a major treatment modality used for the control of advanced stages of malignancies and as a prophylactic against possible metastasis, exhibits severe toxicity on normal tissues.[1, 2] Plants have been used for treating various diseases of human beings and animals since time immemorial. They maintain the health and vitality of individuals, and also cure diseases, including cancer without causing toxicity. More than 50% of all modern drugs in clinical use are of natural products, many of which have the ability to control cancer cells.[3] There are several medicinal plants all over the world, including India, which are being used traditionally for the prevention and treatment of cancer. However, only few medicinal plants have attracted the interest of scientists to investigate the remedy for neoplasm (tumour or cancer). Hence, an attempt has been made to review some medicinal plants which can be used for the prevention and treatment of cancer.In this review some anti cancer plants, the natural product derived from them and their mode of action have been presented. These plants possess effective immunomodulatory and antioxidant properties leading to anticancer activity.

1. *Andrographis Paniculata*

Taxonomic Description and Pharmacological Use

This plant belongs to family Acanthaceae and is popularly known as kalmegh, bhui neem and king of bitters. It is herbaceous plant and mainly its roots ant leaves are used for medicinal purpose. They are used to treat fevers and other ailments due to its cold property.[4] Their pharmacological activities are wide including immunostimulatory, hepatoprotective, anticancerous, anti-HIV activity, anti-fertility and pregnancy terminating effect.[5]

Bioactive Compound and Their Mode of Action

Andrographolide is the main constituent that disrupts the cellular signal transduction pathway of the virus and interferes with their key enzyme and also their reproduction.[6] Their anti-

cancerous activity is mainly due to andrographolide, which acts as a pharmacophore and have both direct and indirect activity on cancerous cells.[7] This compound directly arrests the cell cycle at G0/G1 phase and decrease expression of cyclin dependent kinase.[8,9] They induce apoptosis of human cancer cells through capcase 8 activity by activation of tumor suppression factor p53.[10]

2. *Momordica Charantia*

Taxonomic Description and Pharmacological Use

This is a flowering vine herb of cucurbitaceae family, which is known as bitter gourd or bitter melon and act as nature's silent healer. In common it is popularly known as karela. Its phytochemical constituents include amino acids, enzyme-urease, momorcharins etc.[11,12] They exhibit anti-diabetic[13], anti-tumurous, anti-mutagenic, anti-oxidant activities.[14]

Bioactive Compound and Their Mode of Action

Their bioactive compound viz;momorcharin, momordin and cucurbitacin etc. have cytotoxic activity on canceorous cells. Their phytochemical has the ability to inhibit an enzyme named guanylate cyclise which involves in cancerous growth and in leukemia[15] A chemical analog of their protein named MAP-30 inhibit prostate tumor growth by induced cell apoptosis. Bitter melon extract inhibits breast cancer cell growth by modulating signal transductionandalso used as dietary supplements for prevention of cancers.[16]

Some of them activate AMP-activated protein kinase alpha, which enable glucose uptake and regulate fuel metabolism. They contain artificial insulin i.e. Polypeptide – P which lowers blood sugar level of type-I diabetic patients.

3. *Panax Ginseng*

Taxonomic Description and Pharmacological Use

It is a medicinal herb which belongs to Araliaceae family having five fingered leaves, red berries and five petalled white flowers along with a yellowish brown root.[17] All part of the plant contains bioactive compounds, but mainly roots are used for medicinal purpose. It is commonly known as man-root, ninjin, tartar root, five fingers, etc. They have anti-sterility, adaptogenic, anti-proliferative and memory power enhancing activity. They are also used as sports supplements, and it enhances aerobic capacity of the athlete when supplemented with vitamin-E.[18]

Bioactive Compound and Their Mode of Action

Their bioactive compounds are triterpenoid saponins which is collectively known as ginsenosides or panaxosides. These compounds and their derivatives activate both humoral and cell mediated immune response.They enhances natural killer(NK) cells activity and increases phagocytosis of immune cells.[19] These biochemicals arrest tumorB16-BL6 melanoma cells at G1 phase and also suppresses cyclin-dependent-kinase 2 activity.[20] Ginseng also protects liver cells from radiation and viral hepatitis.[21,22]

4. *Morinda Citrifolia*

Taxonomic Description and Pharmacological Use

It is a broad spectrum evergreen shrub belongs to Rubiaceae family. Commonly it is known as Indian mulberry, cheese fruit, noni, ashyukaetc.[23] It is a hub of medicinal plant from ancient times. Its roots, fruits, bark, stem, leaves all are used to treat specific diseases. Its unripe fruit cure gingivitis, mouth sores, toothaches, high blood pressure, menstrual cramps, food poisoning etc.[24] It has anti-cancerous, anti-depressant, anti-aging, anti-tubercular, anti-helminthic and various other activities. Its ripened fruit have rancid smell with pH 3.5 and it is also used as dietary supplement.

Bioactive Compound and Their Mode of Action

It has various bioactive compounds which are eithervolatile or non-volatile including beta-carotenoids, aucubin, xeronine, alkaloids, allantoin, anthraquinone etc., that have analgesic property and control serotonin level in the body.[25] Its anthroquinone like damacanthal isolated from roots has anti-tumorigenic activity and exhibits cell growth as well as caspase activity induction in colorectal cancer cells.[26] It slows down tumor cell growth and its methanolic extract of fruit juice have immune enhancing capacity and as well prolonged life span of a cancer survivors by stimulating T-cells, thymocytes and macrophages that produce cytokines for tumorcytostasis.[27]

5. *Centella asiatica*

Taxonomic Description and Pharmacological Use

It is herbaceous creeper known as ‘miracle-elixir of life’ and belongs to family Apiaceae. They are commonly known as jalbrahmi, gotukola, Indian pennywort etc. It is a tasteless,

odourless plant having small fan-shaped green leaves, white, light purple or pink flowers and also bears oval shaped fruit. It is used as a contraceptive agent and has anti-fertility activity. Also used as a 'brain tonic' for mentally disabled children. Its pharmaceutical uses are wide in range and also have skin-tightening, and regenerative capacity. It has anti-wrinkling, antipyretic, anti-cancerous properties.

Bioactive Compound and Their Mode of Action

Triparanol, esculetin(phenolics), aesculine/esculin(glucoside), famciclovir, rhoifoline, pelargonic acid, ginkogolide(terpenoid) are bioactive compounds and their drugs which is used to treat patients. Triparanol block proliferation[28] and induce apoptosis in multiple human cancer cells including lung, liver, breast, pancreatic cells etc. whereas esculetin has anti-cancerous, anti-oxidant and neuroprotective activity.[29] Other bioactive compounds are saponins including asiaticoside and medacassoside, alkaloids (vellarine and hydrocotylin), brahmoside, triterpene glycoside, centic acid, asiatic acid etc. This plant methanolic extract inhibit tumor cells growth with no effect on lymphocytes. Its water extract has chemo preventive effect on colon tumourigenesis.[30] Asiatic acid has anti-cancer effect on skin cancers.[31] Asiaticosides enhances collagen synthesis which helps in wound healing activities and also induces apoptosis of tumor cells.

6. *Curcuma longa*

Taxonomic Description and Pharmacological Use: This plant also belongs to the family Zingiberaceae. It is a rhizomatous herbaceous medicinal plant and its common name is Haldi, and used as a flavouring agent in foods and other food items. It is well known for its antiseptic properties from the ancient times. Its rhizome acts as a natural source for active compounds against malignant melanoma. It has anti-venom, anti-HIV, anti-oxidant activities and is highly effective against diabetes, arthritis, alzheimer's disease[32], proapoptotic, immunomodulatory and various other protective activities. It is highly active against breast cancer, bone cancer, liver, cervical, colon, pulmonary and brain cancers.[33]

Bioactive Compound And Their Mode of Action

Curcumin(diferuloylmethane) is a polyphenol[34],the secondary metabolites of the plant are mainly responsible for its colour. As curcumin is not soluble in water, so it becomes difficult for human to digest it easily. This bioactive compound suppresses transformation, proliferation and metastasis of tumors. It also arrest various phase of cancer cell cycle and also inducing apoptosis of malignant cancer cells, which is either mitochondrial dependent or

mitochondrial independent.[35] Curcuminoids protects normal human keratinocytes from hypoxanthine/xanthine oxidase injury. Aromatic-turmerone is very effective against venom, and act s an enzyme inhibitor in case of venom enzymes. It also inhibits telomerase activity which is an important factor for tumorigenesis and causes tumor cell death by generating reactive oxygen intermediates.

7. *Zingiber officinale*

Taxonomic Description and Pharmacological Use

It is a medicinal herbal plant which belongs to Zingiberacae family and its common name is ginger. It is also known as Natural gold, found in nature from ancient times. The genus Zingiber includes 85 species. It is a flowering plant, whose rhizome is simply used for medicinal purposes. Their pharmacological activities include anti-inflammatory activity, anti-cancerous (mostly for colon cancers), anti-oxidants, anti-emetic and anti-arthritic activity. They affect the blood glucose and lipid concentration, blood clotting, blood pressure.

They also have analgesic property, which enhances its pharmacological activity. Neuro protective activity of this plant makes It more valuable.[36] Weight loss, mutagenicity and radio-protective activity of this plant is due to its phenolic compound gingerol.

Bioactive Compound and Their Mode of Action

They contain two different groups of compounds i.e. volatile includes oils and non-volatile includes all bioactive compounds, which is responsible for its pungent smell.[37] The bioactive compounds mainly include gingerol and their analogues such as shogoals, paradolzingerone and galanals A and B which are present in their rhizomes are potent apoptosis inducer in T-lymphocyte cells.[38] The pharmacological activities are mainly due to gingerol and shogoals, which are present in high concentration than others. Steamed ginger (120oC for 4 h) has 1-2 fold higher anti-proliferative activity than dried and fresh ginger due to decrease in amount of gingerols and significantly increase in shogoals which provoke its anticancerous potential.[39] Their compound 6-gingerol inhibits NF-kappaB mechanism in ovarian cells and also inhibits cell adhesion invasion mobility along with 6-shogoal in breast cancer cells in vitro which suppresses tumor growth.[40]

8. *Indigo feratinctoria*

Taxonomoic Description and Pharmacological Use

It is a medicinal herbaceous plant and commonly known as true indigo. It belongs to the Fabaceae family. Their leaves, roots and stems are used for medicinal purpose and are bitter in taste. Their pharmacological activities are anti-bacterial, anti-oxidant, anti-diabetic, anti-hyperglycemic, anti- inflammatery, anti-epilectic, anticancerous and various others. They are also useful in enhancing hair growth.[41]

Bioactive Compound and Their Mode of Action: The bioactive compounds are alkaloids, tannins, flavonoids, phenols saponins, glycosides, anthroquinons,terpenoids etc. these compounds helps in preventing various diseases. Leaves have an active compound Indirubin is an anticancer drug[42] and Indigotin is the active compound with hepatoprotective activity.[43] The aerial parts of plant used for the treatment of anti-proliferative activity in human lung cancer. Dry powder is used in asthma.

9.*Chenopodium album*

Taxonomic Description and Pharmacological Use

They belongs to Chenopodiaceae (Amaranthaceae) family and are commonly known as bathua. They are generally used in food, beverages and are used to cure many blood and heart diseases.

They have anti-oxidant, anti-microbial, anti-hypersensitive, phytotoxic, insecticidal, brine-shrimp cytotoxic activities along with these activities it also provides relief to asthma, migraine and catarrh patients.[44,45]

Bioactive Compounds and Their Mode of Action

The main bioactive compounds are saponins, triterpenoids, flavonoids,allelochemicals etc. The compound kaempferol-40-methoxy-rutinoside exhibited the strongest antioxidant activity than kampeferol 3,7-O-dirhamnoside.[46] Their active methanolic extract has anti cancer activity against the cell lines MCF7 and MDA-MB-468. They induce apoptosis and have cytotoxic effect on tumor cells.[47]

10. *Eucalyptus camaldulensis*

Taxonomic Description and Pharmacological Use

It is a medicinal plant belongs to the family of Myrtaceae and commonly known as red gum tree. Commonly eucalyptus is used in tea, honey and in cough syrups, as air freshener. The oil from leaves used as disinfectant. They have anticancerous, anti- inflammatory, antibacterial and various other anti activities. Its oil is used as antiseptic.

Bio Active Compound and Their Mode of Action

Its leaves contain bioactive compounds like eucalyptol (cineol), tryneol, sesquiterpene alcohols, aliphatic aldehyde, flavonoids, phenols, alcohols isoamyl and terpenes. Its ethanolic leaf extract destroys cancer cells and show cytotoxic effect on K562 cell lines.[48] They inhibit tumor growth by interfering in G2 phase of the cell cycle.[49] In mammals their extracts cause apoptosis by two means i.e. either lateral pathway in which it is mediated by cell surface receptors and by activating the caspase 8, apoptosis signalling pathway is stimulated and then in this cascade mechanism other cascades takes part and causes cellular death whereas the other one is the main pathway, in this cytochrome C is released by mitochondrial membrane depolarization and makes a band with caspase 9 and Apaf-1 and then stimulate the signalling pathway of cellular death and by activating caspase 3, cellular death occurs.[48]

11. *Azadirachta indica*

Taxonomic Description and Pharmacological Use

It is a member of mahogany family Meliaceae, and in India it is commonly known as neem and Indian Lilac. All parts of this tree including leaves, flowers, seeds, roots and even its bark is used for medicinal purposes since ancient times. diuretic, anti-allergenic, chemo preventive, contraceptive, anti viral, anti-bacterial and various other activities.

Bio Active Compound and Their Mode of Action

The bioactive compounds found in this tree are nimbidin, azadirachtin, nimbin, geduninetc. They have mainly flavanoids in almost all their parts. The flavanoid, quercitine has both anti-oxidant and anti-cancerous activity due to its free radical scavenging activity.[50] The active compounds induced apoptosis in various tumor cells and also provoke immune system to take action on the cancer cells through cross priming.[51] This plant releases high amount of antioxidants and carcinogen-detoxifying enzymes. Ethanolic neem leaf extract (ENLE)

modulates gene-expression of various effector molecules involved in cell cycle regulation, apoptosis.

12. *Plumago zeylanica*

Taxonomic Description and Pharmacological Use

Plumago zeylanica commonly known as the Ceylon leadwort or doctorbush is a tropical shrub. Its leaves are widely used in India and China and are believed to kill intestinal parasites. Its other pharmacological properties include antiplasmodial, antifungal, anti-inflammatory, anti-cancerous properties.[52]

Bio Active Compound and Their Mode of Action

Phytochemical screening of P. zeylanica shows that its ethanolic extract contains terpenoids, phytosterols, flavanoids and saponins. Plumbagin, a quinonoid being the most important bioactive compound extracted from its roots is known to have anti-carcinogenic, anti-atherosclerotic and antimicrobial effects. It facilitates autophagic cell death and not apoptosis as shown in two human breast cancer cell lines, MDA-MB-231 and MCF-7 through PI3K/AKT/mTOR inhibition.

PI3K/AKT/mTOR being a signal transduction pathway is important in cell cycle regulation.

It also affects the chemo-sensitivity of tumor cells to anticancer agents.[53] The anticancer potential of this plant is also shown in EAC bearing carcinoma cells due to the presence of high amount of triterpenoids in its leaves and roots.[54]

13. *Santalum album*

Taxonomic Description and Pharmacological Use

Santalum album also known as the tropical or Indian Sandalwood is the member of the family Santalaceae and is the most valuable commercial species due to its high heartwood oil content and fragrance.

It is extensively used in Ayurveda system for treating various ailments likediarrhea with bleeding intrinsic hemorrhage bleeding piles, vomiting, poisoning, initial phase of pox, eye infections, etc. The sandalwood oil is also effective in skin cancers.[55]

Bio Active Compound and Their Mode of Action

The sandalwood essential oil consists of sesquiterpene alcohols α, β, epi-β-santalol and α-exobergamotol.[56] Out of them, α santalol a major component of sandalwood oil is used in

the treatment of various skin ailments, and it also induces glutathione- *S* transferase and acid soluble sulfhydryl levels.[57] It has also been shown to act as a skin cancer chemoprotective agent.[58] It induces apoptosis in human epidermoid carcinoma A431 cells by activation of caspase 8 and 9 which in turn activate caspase 3 and are responsible for the cleavvge of the poly (ADP-ribose) polymerase.[59] It also affects the intrinsic pathway of apoptosis as it dysfunctions the mitochondria by decreasing its membrane potential which marks the release of cytochrome c into the cytosol and results into the activation of caspase and hence apoptosis.[60]

14. *Withania somnifera*

Taxonomic Description and Pharmacological Use

Withaniasomnifera commonly called the Indian ginseng or Ashwagandha, belonging to family Solanaceae forms the traditional system of medicine in India. The entire plant is used for its various pharmacological properties such as anti-cancerous, anti-angiogenesis, anti-metastasis, aphrodisiac, anti stringent and anti inflammatory.[61]

Bio Active Compound and Their Mode of Action: *Withaniasomnifera* is known to produce various biologically active compounds, the most common being the steroidal lactones, withanolides. Withaferin A, a withanolide produced in its leaves is known to inhibit angiogenesis.[62] and metastasis.[63] This property is exhibited by suppression of transcription factor, the Nuclear Factor-κB (NF-κB). This factor is known to be activated by various carcinogens, tumor promoters and most inflamatory agents. It regulates the expresion of genes that regulate transformation, tumor proliferation, tumor invasion, angiogenesis, and metastasis. It also regulates the suppression of apoptosis. Thus withanolide suppression of the NF-κB activation pathway and of the NF-κB regulated gene products controls the tumor cell survival and proves to be anti-cancerous.

15. *Solanum nigrum*

Taxonomic Description and Pharmacological Use

Solanum nigrum commonly known as Black Nightshade is a dicot weed in the Solanaceae family. Solamargine and solasonine, isolated from *Solanum nigrum*inhibit growth & spread of various cancers including that of the breast, liver and lung.[64]

Bio Active Compound and Their Mode of Action

Solamargine and solasonine are the important bioactive agents. Their anti cancerous property is shown by the study on U14 cervical cancer bearing mice where, when the mice was treated with crude polysachharide isolated from Solanum nigrum in vitro, it resulted into arrest of ascites tumor cell in G2/M phase of cell cycle. The invivo treatment resulted into increased expression of Bax and a decreased expression of Bcl-2 and mutant p53 which had a positive correlation with the number of apoptosising tumor cells.[65] Also the treatment decreased the level of blood serum TNF-alpha, this corresponds to triggerring of apoptosis in tumor cells. Another study suggests that the anticancer potential of S. nigrum was based on its capacity to interfere with the structure and function of tumor cell membrane, disturb the synthesis of DNA and RNA, change the cell cycle distribution, blocking the anti-apoptotic pathway of NF-kappaB, activating caspase cascades reaction and increasing the production of nitric oxide. The contribution of autophagic cell death in the anticancer pathways of S. nigrum was carefully elucidated through studies utilising LC3-I and LC3-II proteins in Hep G2 cells.

16. *Glycyrrhiza glabra*

Taxonomic Description and Pharmacological Use

*Glycyrrhiza glabr*a commonly called mulaithi in North India is one of the most important medicinal plant of the family Leguminosae. It is a traditional medicine for coughs, colds and painful swellings.[66] It is used as a laxative, contraceptive, galactagogue, anti-asthmatic drug and antiviral agent.[67] Its roots are used for its demulcent and expectorant and also exihibit antitumor property.

Bio Active Compound and Their Mode of Action

Its root has a no of bioactive compounds like triterpene saponin, flavonoids, polysaccharides, pectin’s, simple sugars, amino acids, mineral salts, asparagines, bitters, essential oil, fat, female hormone estrogen, gums, mucilage(Rhizome), protein, resins, starches(30%), sterols, volatile oils, tannins, glycosides, and various other substances[68], most important being the Glycyrrhizin-a triterpenoid compound responsible for sweet taste of licorice root.

The aqueous extract or *G. glabra* inhibits *in vivo* and *in vitro* proliferation or Ehrlich ascites tumor cells and inhibits angiogenesis in *in vivo* assay, peritoneal and choreoallantonic membrane assay.[69] Glycyrrhetic acid could also trigger the pro-apoptotic pathway by inducing mitochondrial permeability transition and this property may be useful for inducing apoptosis of tumor cells.[70]

17. *Catharanthus roseus*

Taxonomic Description and Pharmacological Use

Catharanthus roseus commonly known as The Madagaskar Periwinkle is a tropical, subtropical herbaceous plant belonging to family Apocynaceae. There are two common cultivars of C.roseusviz; Rosea (pink flowered) and Alba (white flowered) based on the color of its flower. It is a plant of great medicinal importance and is also appreciated as an ornamental plant.[71] Its pharmacological properties include anti-cancerous, anti-leukaemic, anti-hypersensitive, antioxidant, etc.

Bio Active Compound and Their Mode of Action

Catharanthus roseus produce a wide array of 130 complex alkaloids.[72] Out of which it accumulates in its leaves the dimeric terpenoid indole alkaloids (TIAs): vinblastine and vincristine that are the first natural anticancer agents to be used clinically with a number of semi synthetic derivatives known as Vinca alkaloids. These alkaloids are used against a number of cancers. They are able to inhibit cancer cell growth during metaphase leading to cell death; they cause apoptosis rather than necrosis in human neuroblastoma cell line SH-SY5Y.[73] The NF-κB/IκBsignaling pathway m-ay contribute to the mediation of vinca alkaloid-induced apoptosis in human tumor cells.[74] Vinca alkaloids increase apoptosis by increasing concentrations of the cellular tumor antigen p53 and cyclin-dependent kinase inhibitor 1 (p21), and by inhibiting Bcl-2 activity.[75]

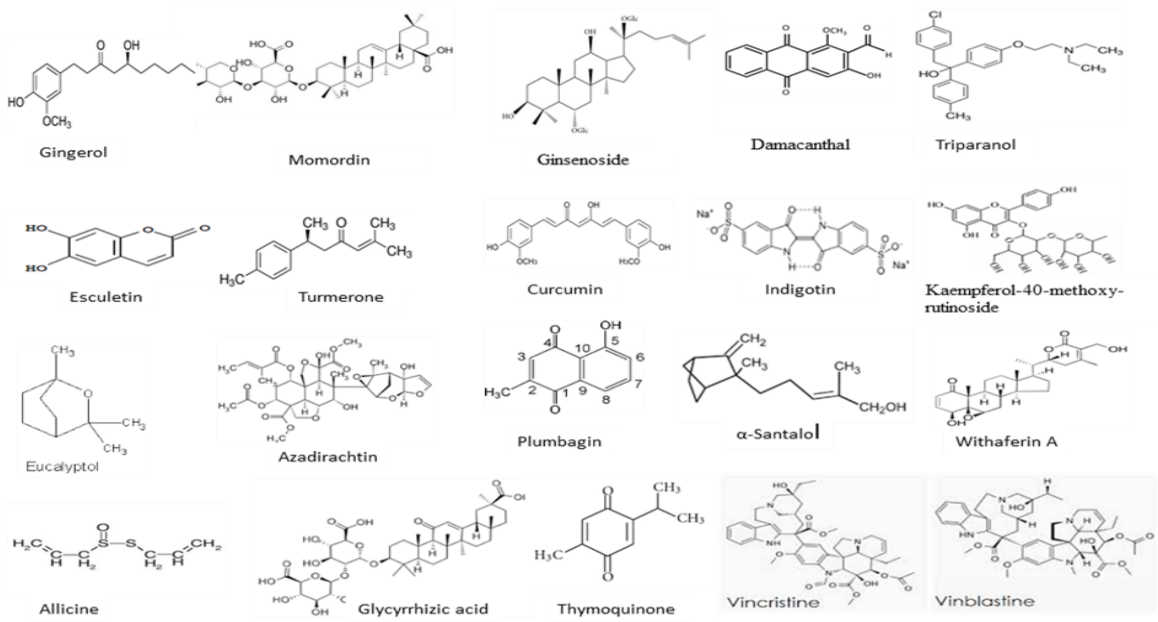

Figure 1.Chemical structures of some of bioactive compounds of medicinal plants with anti-cancerous activity

Table: 1. Bioactive compounds and therapeutic activities of medicinal plants.

S.NO	SCIENTIFIC NAME	COMMON NAME	AERIAL PARTS	BIOACTIVE COMPOUNDS	BIOLOGICAL ACTIVITY	MODE OF ACTION
1	Andrographis paniculata	kalmegh, bhui neem	leaves, roots, stem	phenolics, phenolic acid	antioxidant	Enzyme inhibition by oxidised compound in microorganisms.[76]
					Antiinflammatory	Prevent oxygen radical formation in human neutrophils[77]
2	Momordica charantia	bitter gourd, karela	fruits	charantins	Anti diabetic	Decreases blood sugar level by enhancing cell's uptake of glucose and promoting insulin release by activating protein kinase alpha.[78]
			leaf extract	α and β monorcharin	anti-HIV	Loss of viral antigen and inhibit viral protein synthesis.[79]
3	Panax ginseng	man-root, ninjin, tartar root, five fingers	roots	ginsenoside, ginseng	Immune modulatory	enhances Nkcell activity and increases immune cell phagocytosis after ginsenoside exposure.[19]
					antioxidant	Enhances self-antioxidant enzyme activities.[80]
					Anti inflammation	Suppresses inflammatory cytokines and chemokines.[81]
4	Morinda citrifolia	Indian mulberry, noni fruit	roots, fruits	anthraquinone	antigenotoxicity	Control oxidative damage.[82]
				damacanthal	antiviral	Suppresses cytopathic effect of HIV infected MT-4 cells.[83]
					antioxidant	Neutralises ROS - reactive oxygen species.[82]
5	Curcuma longa	turmeric, haldi	roots	curcumin	radioprotectant	Induces the activation of nuclear factors.[84]
					antioxidant	Inhibit lipid peroxidation.[85]
6	Indigofera tinctoria	true indigo, neel	leaves, roots and stems	phenolics	antioxidant	inhibits enzyme activity responsible for free radical formation, chelating metal ions and scavenging ROS.[86]

7	Eucalyptus camaldulensis	red gum tree	leaf stem, bark	acetone, methanol and water extract	antimicrobial	Toxic to microorganisms[87]
					antiradical	Enhances antioxidant enzymes activity.[88]
8	Catharanthus roseus	sadabahar	whole plant	tannins, phenolics, flavanoida	anti-oxidant	Singlet oxygen quencher, oxygen radical absorbance capacity.[89]
9	Plumago zeylanica	doctorbush, chitrak	ethanol extract of leaves	plumbagin, lupeol, napthaquinone	antifertility	Interrupt the estrous cycle and inhibit ovulation.[90]
			ethanol extract of roots		antioxidant	By free radical scavenging activity.[90]
10	Santalum album	sandalwood, chandan	whole plant	α-santalol	antioxidant	scavenges free radicals of NO
11	Withania somnifera	indian ginseng, ashwagandha	leaf, roots	withaferin A and withanolide D and E	radioprotectant	Increase in heme oxygenase activity and reduced GSH content.[91]
12	Solanum nigrum	black nightshade, wonder berry, makoi	whole plant	Solamargine and solasonine	hepatoprotective	Decreases AST, ALT, ALP and bilirubin concentration.
					antioxidant	Scavenges free radicals.[92]
13	Glycyrrhiza glabra	mulaithi	roots, rhizome	glycyrrhizin, glabridin	antioxidant	Inhibit generation of ROS by neutrophils.[93]
				glycyrrhizic acid	anticoagulant	Inhibits cyclo-oxygenase activity and prostaglandin formation.
				liquorice	hepatoprotectant	Lowering serum enzyme level.[94]
14	Nigella sativa	black cumin, kalonji	seeds, oil	nigellone, thymoquinone	antidiabetic	Inhibition of hepatic gluconeogenesis and also stimulate pancreatic β cell activity.[95]
				thymoquinone and its derivatives	antioxidant	Inhibit iron dependent microsomal lipid peroxidation.[96]

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