Screening of Anticancer Properties of some Medicinal Plants - Review

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ABSTRACT

Cancer is the most deadly disease in the world and cancer deaths are increasing rapidly in developed and developing countries. There are many types of cancer affecting people of all ages with no discrimination of age and sex. Treatment options are synthetic drugs and naturally derived drugs. The synthetic drugs have many side effects and are not preferred and there is a dire need to have a natural anticancer drug with novel mechanism of action. The plant kingdom with its vast diversity, rich secondary metabolites, easy availability makes them most popular for discovering new anticancer compounds. With this idea, in this review, 50 medicinal plants belonging to 34 families were screened for their anticancer properties. They were used as plant extracts or essential oils or metal nanoparticles. Detailed information is also given regarding the part used, solvent used, assay and cell lines used for evaluating the anticancer properties. These are promising plants and hence potential candidates for further studies which may ultimately lead to new drugs or lead molecules for drug development to be used as natural, novel and safe anticancer agents.

Keywords
Medicinal plants, anticancer activity, MTT assay, cell lines, in vitro methods

Introduction

Cancer is a major health hazard both in developed and developing countries and is the second leading cause of death worldwide. It is a frightful and most devastating disease and main cause of morbidity and mortality globally; the number of cases of cancer deaths are increasing rapidly and estimated to be 21 million by 2030 (Siegel et al., 2016). Cancer is a complex disease with more than 100 disorders. It induces abnormal cell growth which spreads to different parts of the body and result in their dysfunction. According to GBD (2015) Disease and Injury Incidence and Prevalence Collaborators (2016) and WHO (2016), 8.8 million deaths occurred due to various types of cancer in 2015. According to Ruckmani et al., (2015), in India 5.5 lakh deaths occur every year and 8 lakh cases are detected.

There are many types of cancer like lung, colon, cervical, prostrate, hepatic, blood, pancreatic, renal, skin, breast but most common are breast, colon, prostrate, and lung.
cancer. Cancer may affect people of all ages but chances increase with age. It is estimated rather statistics indicate that men are prone to lung, colon, rectum and prostate cancer while women are prone to breast, colon, rectal and stomach cancer. Even children below 15 years are prone to cancer mainly because of lifestyle and eating habits (Sirsat et al., 2019).

Treatment options for cancer are chemotherapy, brachytherapy, cryosurgery, hormonal therapy, surgery and chemically derived drugs. Many synthetic anticancer or antitumor drugs are used to treat cancer but there are many side effects like myelosuppression, hair loss, fatigue, infection, etc (Stopeck and Thompson, 2012; Hu et al., 2015).

In fact, chemotherapeutic drugs lead to various side effects while natural anticancer drugs derived from medicinal plant extracts, essential oils or metal nanoparticles selectively induce apoptosis and arrest cancer cells without causing any damage to normal cells (Shahneh et al., 2014).

One of the criterions for an effective and acceptable anti-cancer agent/drug is that it should have no harmful effect on normal cells. Cell cycle arrest of cancer cells is regarded as one of the target mechanisms in cancer treatment (Diaz-Moralli et al., 2013). Various compounds isolated from plants are effective against proliferating cells.

They exhibit cytotoxic effects either by damaging DNA or by blocking the formation of mitotic spindle during different stages of cell division (Gali-Muhtasib and Bakkar, 2002). The need of the hour is to isolate bioactive compounds from medicinal plants that can be a lead molecule for anticancer drug therapy or to develop the crude plant extract itself to become herbal medicine (Singh et al., 2013).

There are a number of anticancer drugs already in use, which are of plant origin. Few examples are vinca alkaloids, vinblastine and vincristine from Catharanthus roseus; Paclitaxol (taxol) from Taxus brevifolia; Himoharringtonine from Cephalotaxus harringtonia; Elliptinium, a derivative of ellipticine isolated from Bleekeria vitensis; Colchicine from Colchium autumnale (Nagani and Chanda, 2013; Iqbal et al., 2017; Seca and Pinto, 2018). There are many medicinal plants which show anticancer properties (Chanda and Nagani, 2013; Sirsat et al., 2019).

Plant compounds with anticancer properties are polyphenols, brassinosteroids and taxols. Polyphenols include flavonoids, tannins, curcurmin, resveratol and gallacatechins. Flavonoids include anthocyanins, flavones, flavonols, chalcones, etc. Two natural brassinosteroids which showed anticancer properties are 28-homocastasterone and 24-epibrassinolide (Greenwell and Rahman, 2015).

Plant and plant derived drugs are better alternatives to chemical or synthetic drugs because natural drugs are simple, safe, eco-friendly, economic, less toxic with less side effects; marine and microbiological organisms have also provided many promising bioactive anticancer compounds for eg. trabectedn, cytotoxic antibiotics of the anthracycline class and enedynes (Amaral et al., 2019).

The anticancer properties of medicinal plant extracts can be evaluated by various in vitro and in vivo models. Some screening in vitro methods for anticancer activity are Tryphan blue dye exclusion assay, Lactate dehydrogenase assay, MTT (3-[4,5-dimethylthiazol-2-yl]-2,5-diphenyltetrazolium bromide) assay, XTT (2,3-bis[2-Methoxy-4-nitro-5-sulfophenyl]-2Htetrazolium-5-
carboxyanilide inner salt) assay, NRU (Neutral red uptake assay) and SRB (Sulforhodamine B assay); but most popular is MTT assay (Chanda and Nagani, 2013). MTT assay is non-radioactive, quick, simple and affordable method widely used in cytotoxic studies (Russo et al., 2004). Induction of Ehrlich ascites carcinoma in mice represents the in vivo model (Devi et al., 1998).

In MTT assay, different types of cell lines are used for eg. HeLa, PLHC-1, Calu-6 and U251, Ca Ski-, MV-3 (cervical cancer cell lines), T47D, MDA-MB-435S, MDA-MB-231 and MCF-7, MCF-12A, Bcap-37, HCC1937 and HCC1143(breast cancer cell lines), L929 (normal fibroblast cancer cell line), HaCaT (human immortalized keratinocytes cells), A-549, Mehr-80, NCI-460, , NCI-H460, HOP-6 (lung cancer cell line), HCT-116, HT-29, WiDr, LoVo (colon cancer cell line), CACO-2 (intestinal cancer cell line), MIAPaCa-2, PANC-1 (pancreatic cancer cell line), MGC-803, ATCC-43504 (human gastric cancer cell line), PA-TU-8902 (pancreas adenocarcinoma cell line), Hep2 (human epiglottis cancer line), WEHI, SAF-1, K-562,THP1 (leukemia cancer cell line), HepG2 (hepatocarcinoma cell line), HEK293, 786-0 (human renal cell lines), OVCAR-03, IGR-OV-1 (ovarian cancer cell line), PC-3, DU145, LNCaP (prostate cancer cell lines), HEK 293, HEK 293T (human kidney cell lines), SMMC-7721 (hepatoma cancer cell line), U251 – (human tumor cell lines) KB, HEP-2 (nasopharyngeal epidermoid cancer cell line), WISH (human amniotic epithelial cell line), Vero (African green monkey kidney cell line), RAW 264.7 (Murine macrophage cancer cell line), WRL-68 –(normal human hepatic cell line), Jurkat -Human T-cell lymphoma, etc.

The plant extracts, essential oils or nanoparticles are rich in many different phytoconstituants and all work in different manner. Anticancer agents act via many mechanisms. They induce cell cycle arrest and apoptosis; suppress proliferation of cells, inhibit cell cycle progression, inhibit DNA synthesis, rupture plasma membrane, activate caspases, depolarize mitochondria; modulation signal transduction, etc (Saklani et al., 2019). A direct correlation between antioxidant activity and antiproliferative activity is reported by Liu et al., (2002) in Rubus idaeus; Ghasemzadeh et al., (2018) in Oryza sativa; Wang et al., (2019) in Boehmeria nivea plants.

In the present review, a number of plants, parts and solvents used, cytotoxicity assay and cell lines used, metal nanoparticles used for evaluating cytotoxic potential of medicinal plants is listed (Table 1). Screening of 50 plants was attempted. The 50 plants belonged to 34 different families, in which 8 plants belonged to Lamiaceae family, 6 plants belonged to Fabaceae family, 2 plants belonged to Malvaceae family, 2 plants belonged to Compositae/Asteraceae family, 2 plants belonged to Moraceae family, 2 plants belonged to Malvaceae family, 2 plants belonged to Compositae/Asteraceae family, 2 plants belonged to Malvaceae family, 2 plants belonged to Caesalpiniaceae family and 2 plants belonged to Rosaceae family.

Different plant extracts showed promising activity against different types of cancer. The parts of the plant used and solvent extracts were also different but they were very effective against a varied number of cancer types. For eg. roots of R. cordifolia on kidney, cervical larynx carcinoma (Patel et al., 2011); seeds of S. macrophylla on colon carcinoma, nasopharyngeal epidermoid carcinoma, cervical carcinoma and breast carcinoma (Goh and Kadir, 2011); seeds A. heterophyllus embryonic kidney, lung adenocarcinoma, cervical and breast cancer (Patel and Patel 2011); roots of P. longipes, S. miltiorrhiza, S. sahendica on pancreatic and
melanoma cancer (Fronza et al., 2011); rhizomes of A. mutica on epidermoid, breast, lung, cervical, colon, non-human fibroblast carcinoma (Malek et al., 2011); leaves of A. indica on breast adenocarcinoma (Bibi et al., 2012); seeds of M. oleifera on lung, liver, colon, neuroblastoma (Shaban et al., 2012); muricatan leaves on human hepatic, breast carcinoma and immortalized keratinocyte (George et al., 2012); seeds of T. foenum graecum on epidermoid, breast adenocarcinoma (Al-Oqail et al., 2013); leaves of B. variegate on ovary, prostrate, lungs, breast, leukemia cancer (Mishra et al., 2013); silver nanoparticles of C. guianensis on breast cancer (Devaraj et al., 2013); peel of H. polyrhizus and H. undatus on prostate, breast and gastric cancer (Luo et al., 2014); fruit kernels of M. indica on breast cancer (Abdullah et al., 2014); seeds of N. sativa on lung cancer (Al-Sheddi et al., 2014); Mistletoe of V. album on breast carcinoma, pancreas adenocarcinoma, prostate carcinoma, lung carcinoma (Weissenstein et al., 2014); seeds of P. cubeba on breast cancer (Graidist et al., 2015); G. glabra, P. lactiflora, and E. japonica on murine macrophage (Zhou et al., 2015); zinc oxide nanoparticles of D. regia on lung cancer (Sathyabama and Sankaranarayanan, 2015); gold nanoparticles of T. terrestris on adenocarcinoma (Gopinath et al., 2016); wood of L. amara on cervical and breast cancer (Zubair et al., 2016); fruits of O. bacaba on breast cancer (Finco et al., 2016); bark and leaf of P. eldarica on cervical and breast cancer (Sarvmeili et al., 2016); A. odorata leaves on breast adenocarcinoma (Boutennoun et al., 2017); aerial parts of O. vulgare on hepatocellular carcinoma and embryonic kidney (Elshafie et al., 2017); M. nigra fruit on prostate adenocarcinoma (Turan et al., 2017); O. vulgare leaves on kidney leucocyte and tumor (Beltrán et al., 2017); aerial parts of D. kotschyi on pulmonary adenocarcinoma and lung cancer (Sani et al., 2017); methanol extract of leaf, stem and bark of Pterocarpus santalinus on human cervical cancer (Donga et al., 2017), Leea indica leaves on human prostate cancer (Ghagane et al., 2017), root bark of Crataeva magna on Ehrlich ascites carcinoma (Meera and Chidambaranathan, 2017), aerial parts of T. vulgaris on human tumor, colon, intestinal and breast carcinomas (Hassan et al., 2018); fruits of R. canina on colon cancer (Turan et al., 2018); whole plant of S. barbata on hepatoma, colon and breast cancer (Wang et al., 2018); leaves and stem of T. hypoleuca on melanoma, breast, kidney, lung, prostate, ovary, colon and leukemia cancer (Perera et al., 2019); leaves, fruits and seeds of A. obesum on breast cancer (Ali et al., 2019); leaves of C. sativus on breast and cervical cancer (Tuama and Mohammed, 2019); bark of A. lebbeck on breast cancer (Sivraj et al., 2019); silver nanoparticles of M. umbellatum on breast cancer (AlSalhi et al., 2019); aerial parts of S. officinalis on prostate, breast and cervical cancer (Privitera et al., 2019); gold nanoparticles of S. barbata on pancreatic cancer (Wang et al., 2019); copper nanoparticle of T. japonica on colon, hepatic and breast cancer (Hassanien et al., 2019); copper nanoparticle of S. alternifolium on breast cancer (Yugandha et al., 2019), leaves of Aloe castellorum and Aloe pseudorubroviolacea on colon carcinomas (Ahmed et al., 2020); aerial parts of Azadirachta indica and Melia azedarach on breast cancer (Malar et al., 2020); silver nanoparticles of Tamarindus indica on breast cancer (Gomathi et al., 2020); whole plants of Rumex vesicarius on breast, colon and liver carcinoma (Farooq et al., 2020), etc.

The promising activity of these plants as anticancer agents is because of the secondary metabolites present in them. The secondary metabolites may be alkaloids, flavonoids, phenols, tannins, terpenoids, anthraquinones, saponins and may be obtained from any part
of the plant and not restricted to any particular plant organ. The secondary metabolites may be present in plant aqueous extract, or organic solvent extracts, essential oils, or nano particles synthesized using any plant part (Sirsat et al., 2019). Phenols and flavonoids derived from medicinal plants showed anticancer properties (Gibellini et al., 2010; Mavundza et al., 2010). Anti cancer property of A. indica and M. azedarach extracts is reported by Malar et al., (2020). Both these plants showed the presence of secondary metabolites like flavonoids, phenols, steroids, alkaloids, tannins, saponins, anthraquinones, etc. Different medicinal plants listed in Table 1 showed anticancer properties and it is attributed for the presence of various phytochemicals in them.

For eg. n- hexane extract of P. longipes contained 7α-acetoxyroyleanone, horminone, royleanone, 7-ketoroyleanone, 7α-ethoxyroyleanone, iguestol, deoxyneocryptotanshinone, 12-hydroxy-11-methoxyabieta-8,11,13-trien-7-one, inuroyleanol, sugiol, cryptojapanol, orthosiphonol; n- hexane extract S. miltiorrhiza contained tanshinone, cryptotanshinone, tanshinone i, 1,2-dihydrotanshinone, miltirone, 1-oxomiltirone, miltiodiol, ferruginol, sahandinone, camptothecin (Fronza et al., 2011); ethyl acetate extract of A. mutica contained flavokawin B, 5,6-dehydrokawain, alpinetin, pinostrobin chalcone (Malek et al., 2011); n-butanol leaf extract of Annona muricata contained flavonols, polyphenols and flavones (George et al., 2012); different solvent extracts of B. variegata contained terpenoids, phenolics, flavonoids, anthraquinones, saponins, tannins, alkaloids (Mishra et al., 2013); supercritical carbon dioxide extracts of pitaya H. polyrhizus and H. undatus peel contained β-amyrin, β-sitosterol, and stigmaster-4-en-3-one, octadecane, 1-tetracosanol, Heptacosane, campesterol, nonacosane, trichloroacetic acid, hexadecyl ester (Luo et al., 2014); methanol extract of P. cubeba contained monoterpenes, sesquiterpenes, β-elemene, β-cubebene, β-pinene (Graidist et al., 2015); ethanolic extract of Mangifera indica contained phenol, 4,6-di (1,1-dimethylthyl)-2-methyl (Abdullah et al., 2014); methanolic extract of L. amara contained alkaloids and lunacrine (Zubair et al., 2016); ethanolic extract of Crateva magna contained flavonoids, alkaloids and tannins (Meera and Chidambaranathan, 2017); aqueous and ethanolic extracts of O. vulgare contained phenolic compounds, flavonoids, chlorogenic, caffeic, pcoumaric, furlic, rosmarinic and ursolic acids p-cymene, l-octacosanol and phytol (Beltrán et al., 2017); dimethyl sulfoxide extract of M. nigra contained ascorbic acid, gallic acid, 3,4-dihydroxy benzoic acid, protocatechuic acid, chlorogenic acid, caffeic acid, epigallocatechin gallate, p-coumaric acid, rutinhydrate (Turan et al., 2017); essential oils of O. vulgare contained limonene, thymol, carvacrol ,citral (Elshafie et al., 2017); essential oil of T. vulgaris contained P-cymene, γ terpenine, thymyl methyl ether, thymol, p-cymene, o-cymene (Hassan et al., 2018), etc. different solvent extracts from T. rosea contained o-xylene, 2,4-dimethylhexane, methyl cyclohexane, methylbenzene, 3-Pentene-2-one, alkaloid and pentacyclic triterpenes (Perera et al., 2019); methanol bark extract of A. lebbeck contained 2-(4-methyloctadecanoyl)imidazole, levo-5a-dihydroxornestrel, 9-octadecyonoic acid, methyl ester, octadec-9-enoic acid, 10-octadecenoic acid, methyl ester, dodecanoic acid, 11-oxo-methyl ester, 4,7-methanoazulene, decahydro - 1,4,9,9-tetramethyl, benzene, 1-pentynyl, benzene, 1,4-bis(4-acetylphenyliminomethyl), 4h-benzopyron-4-one,7-hydroxy (Sivaraj et al., 2019), etc.
## Table 1 List of medicinal plants, their family, parts, solvents used for extraction, assay and cell line employed for cytotoxicity studies

<table>
<thead>
<tr>
<th>Sr. No</th>
<th>Botanical name (family)</th>
<th>Plant part</th>
<th>Solvent / Essential oil/ Nanoparticle</th>
<th>Assay/ Cell line</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Abelmoschus esculentus L. (Malvaceae)</td>
<td>fruit pulp</td>
<td>silver nanoparticles</td>
<td>MTT assay- Jurkat cell line</td>
<td>Mollick et al., 2015</td>
</tr>
<tr>
<td>2</td>
<td>Achillea odorata L. (Asteraceae)</td>
<td>leaf</td>
<td>methanol</td>
<td>MTT assay- MCF-7, Hep2, WEHI</td>
<td>Boutennoun et al., 2017</td>
</tr>
<tr>
<td>3</td>
<td>Adenium obesum (Forssk.) Roem. &amp; Schult.(Apocynaceae)</td>
<td>leaf, fruit, seed</td>
<td>95% ethanol, aqueous</td>
<td>MTT assay-MCF-7</td>
<td>Ali et al., 2019</td>
</tr>
<tr>
<td>4</td>
<td>Aesculus indica L. (Sapindaceae)</td>
<td>leaf</td>
<td>methanol, aqueous</td>
<td>MTT assay-MCF-7</td>
<td>Bibi et al., 2012</td>
</tr>
<tr>
<td>5</td>
<td>Albizia lebbeck L. (Fabaceae)</td>
<td>bark</td>
<td>methanol</td>
<td>MTT assay-MCF-7</td>
<td>Sivaraj et al., 2019</td>
</tr>
<tr>
<td>6</td>
<td>Aloe castellorum J.R.I.Wood Aloe pseudorubroviolacea L. (Asphodelaceae)</td>
<td>leaf</td>
<td>methanol</td>
<td>MTT assay-HCT-116</td>
<td>Ahamed et al., 2020</td>
</tr>
<tr>
<td>7</td>
<td>Alpinia mutica Roxb. (Zingiberaceae)</td>
<td>rhizome</td>
<td>methanol, hexane, ethyl acetate, aqueous</td>
<td>(NRU) Neutral red uptake assay-KB,MCF7,A549 Ca Ski, HCT116, HT29,MRC5</td>
<td>Malek et al., 2011</td>
</tr>
<tr>
<td>9</td>
<td>Artocarpus heterophyllus Lam. (Moraceae)</td>
<td>seed</td>
<td>methanol</td>
<td>MTT assay-HEK 293T, A549, HeLa, MCF-7</td>
<td>Patel and Patel 2011</td>
</tr>
<tr>
<td>10</td>
<td>Azadirachta indica A. Juss Melia azedarach L. (Meliaceae)</td>
<td>aerial parts</td>
<td>petroleum ether, methanol, hexane, aqueous</td>
<td>MTT assay-MCF-7</td>
<td>Malar et al., 2020</td>
</tr>
<tr>
<td>11</td>
<td>Bauhinia variegate L. (Leguminosae/ Fabaceae)</td>
<td>leaf</td>
<td>petroleum ether, benzene, chloroform, ethyl acetate, acetone, ethanol, aqueous</td>
<td>SRB assay-IGR-OV-1, DU-145, HOP-6, MCF-7, THP1</td>
<td>Mishra et al., 2013</td>
</tr>
<tr>
<td>No.</td>
<td>Species</td>
<td>Type</td>
<td>Extracts/Compounds</td>
<td>Assay</td>
<td>References</td>
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<tr>
<td>12</td>
<td><em>Caesalpinia pulcherrima</em> L. (Caesalpiniaceae)</td>
<td>flower</td>
<td>silver nanoparticles</td>
<td>MTT assay HeLa</td>
<td>Moteriya and Chanda, 2017</td>
</tr>
<tr>
<td>13</td>
<td><em>Couroupita guianensis</em> Aubl. (Lecythidaceae)</td>
<td>leaf</td>
<td>silver nanoparticles</td>
<td>MTT assay- MCF-7</td>
<td>Devaraj <em>et al.</em>, 2013</td>
</tr>
<tr>
<td>14</td>
<td><em>Cucumis sativus</em> L. (Cucurbitaceae)</td>
<td>leaf</td>
<td>methanol, acetone</td>
<td>MTT assay-MCF 7, HeLa</td>
<td>Tuama and Mohammed, 2019</td>
</tr>
<tr>
<td>15</td>
<td><em>Delonix regia</em> L. (Caesalpiniaceae)</td>
<td>flower</td>
<td>zinc oxide nanoparticles</td>
<td>MTT assay-A549</td>
<td>Sathyabama and Sankaranarayanan, 2015</td>
</tr>
<tr>
<td>16</td>
<td><em>Dracocephalum kotschyi</em> Boiss. (Lamiaceae)</td>
<td>aerial part</td>
<td>methanol, dichloromethane, ethyl acetate, hexane, aqueous, essential oil</td>
<td>MTT assay- Calu-6, Mehr-80, L929</td>
<td>Sani <em>et al.</em>, 2017</td>
</tr>
<tr>
<td>17</td>
<td><em>Glycyrrhiza glabra</em> L. (Fabaceae) <em>Paeonia lactiflora</em> Pall. (Paeoniaceae) <em>Eriobotrya japonica</em> (Thunb.) Lindl (Rosaceae)</td>
<td>-</td>
<td>methanol, 50% ethanol, 96% ethanol,</td>
<td>MTT assay- RAW 264.7</td>
<td>Zhou <em>et al.</em>, 2015</td>
</tr>
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<td>19</td>
<td><em>Lunasia amara</em> Blanco. (Rutaceae)</td>
<td>wood</td>
<td>methanol, ethyl acetate, n-hexane</td>
<td>MTT assay- HeLa, T47D</td>
<td>Zubair <em>et al.</em>, 2016</td>
</tr>
<tr>
<td>21</td>
<td><em>Memecylon umbellatum</em> Burm F. (Melastomataceae)</td>
<td>leaf</td>
<td>silver nanoparticles</td>
<td>MTT assay-MCF-7</td>
<td>AlSalhi <em>et al.</em>, 2019</td>
</tr>
<tr>
<td>23</td>
<td><em>Morus nigra</em> L. (Moraceae)</td>
<td>fruit</td>
<td>dimethyl sulfoxide</td>
<td>MTT assay- PC-3</td>
<td>Turan <em>et al.</em>, 2017</td>
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<tr>
<td>24</td>
<td><em>Nigella sativa</em> L. (Ranunculaceae)</td>
<td>seed</td>
<td>essential oil, ethanol</td>
<td>MTT assay- A-549</td>
<td>Al-Sheddi <em>et al.</em>, 2014</td>
</tr>
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<td>25</td>
<td><em>Oenocarpus bacaba</em> Mart. (Arecaceae)</td>
<td>fruit</td>
<td>80% acetone</td>
<td>Methyle blue assay- MCF-7</td>
<td>Finco <em>et al.</em>, 2016</td>
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<td>26</td>
<td><em>Origanum vulgare</em> L.</td>
<td>aerial</td>
<td>essential oils</td>
<td>MTT assay-</td>
<td>Elshafie <em>et al.</em>,</td>
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<tr>
<td></td>
<td>(Lamiaceae)</td>
<td>part</td>
<td>HepG2, HEK293</td>
<td>2017</td>
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<tr>
<td>27</td>
<td><em>Origanum vulgare</em> L. (Lamiaceae)</td>
<td>leaf</td>
<td>aqueous ethanol</td>
<td>MTT assay</td>
<td>Beltrán et al., 2018</td>
</tr>
<tr>
<td>28</td>
<td><em>Peltophorum pterocarpum</em> (DC.) (Fabaceae)</td>
<td>root</td>
<td>n-hexane</td>
<td>MTT assay</td>
<td>Fronza et al., 2011</td>
</tr>
<tr>
<td>29</td>
<td><em>Origanum vulgare</em> L. (Lamiaceae)</td>
<td>leaf</td>
<td>aqueous ethanol</td>
<td>MTT assay</td>
<td>Beltrán et al., 2018</td>
</tr>
<tr>
<td>30</td>
<td><em>Peltodon longipes</em> Benth.</td>
<td>root</td>
<td>n-hexane</td>
<td>MTT assay</td>
<td>Beltrán et al., 2018</td>
</tr>
<tr>
<td>31</td>
<td><em>Piper cubeba</em> L. (Piperaceae)</td>
<td>seed</td>
<td>methanol</td>
<td>MTT assay</td>
<td>Graidist et al., 2015</td>
</tr>
<tr>
<td>32</td>
<td><em>Rhododendron arboretum</em> Sm. (Ericaceae)</td>
<td>leaf, flower</td>
<td>methanol</td>
<td>MTT assay</td>
<td>Gautam et al., 2018</td>
</tr>
<tr>
<td>33</td>
<td><em>Rosa canina</em> L. (Rosaceae)</td>
<td>fruit</td>
<td>dimethyl sulfoxide</td>
<td>MTT assay</td>
<td>Turan et al., 2018</td>
</tr>
<tr>
<td>34</td>
<td><em>Rubia cordifolia</em> L. (Rubiaceae)</td>
<td>root</td>
<td>methanol, petroleum ether, dichloromethane</td>
<td>XTT assay</td>
<td>Patel et al., 2011</td>
</tr>
<tr>
<td>35</td>
<td><em>Ruellia britoniana</em> L. (Acanthaceae)</td>
<td>flower</td>
<td>n-hexane, ethyl acetate, ethanol</td>
<td>MTT assay</td>
<td>Tejaputri et al., 2020</td>
</tr>
<tr>
<td>36</td>
<td><em>Rumex vesicarius</em> L. (Polygonaceae)</td>
<td>whole plant</td>
<td>methanol, chloroform, hexane, ethyl acetate</td>
<td>MTT assay</td>
<td>Farooq et al., 2020</td>
</tr>
<tr>
<td>37</td>
<td><em>Salvia officinalis</em> L. (Lamiaceae)</td>
<td>aerial part</td>
<td>essential oil</td>
<td>MTT assay</td>
<td>Privitera et al., 2019</td>
</tr>
<tr>
<td>38</td>
<td><em>Scutellaria barbata</em> D.Don (Lamiaceae)</td>
<td>whole plant</td>
<td>acetone</td>
<td>MTT assay</td>
<td>Wang et al., 2018</td>
</tr>
<tr>
<td>39</td>
<td><em>Scutellaria barbata</em> L.(Lamiaceae)</td>
<td>whole plant</td>
<td>gold nanoparticles</td>
<td>MTT assay</td>
<td>Wang et al., 2019</td>
</tr>
<tr>
<td>40</td>
<td><em>Swietenia macrophylla</em> King. (Meliaceae)</td>
<td>seed</td>
<td>ethanol</td>
<td>MTT assay</td>
<td>Goh and Kadir, 2011</td>
</tr>
<tr>
<td>41</td>
<td><em>Syzygium alternifolium</em> (Wt.)</td>
<td>stem, bark</td>
<td>copper nanoparticles</td>
<td>MTT assay</td>
<td>Yugandhar et al., 2019</td>
</tr>
<tr>
<td>(Myrtaceae)</td>
<td>42</td>
<td>Tabebuia hypoleuca (C. Wright) Urb. (Bignoniaceae)</td>
<td>leaf, stem</td>
<td>n-hexane, ethyl acetate, methanol</td>
<td>MTT assay - U251, MCF-7, NCI-460, OVCAR-03, PC-3, HT-29, 786-0, K-562</td>
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<tr>
<td>43</td>
<td>Tamarindus indica L. (Fabaceae)</td>
<td>fruit shell</td>
<td>silver nanoparticles</td>
<td>MTT assay - MCF-7</td>
<td>Gomathi et al., 2020</td>
</tr>
<tr>
<td>44</td>
<td>Thymus vulgaris L. (Lamiaceae)</td>
<td>aerial part</td>
<td>essential oils</td>
<td>A-549, HCT-116, CACO-2, MCF-7</td>
<td>Hassan et al., 2018</td>
</tr>
<tr>
<td>45</td>
<td>Tilia japonica L. (Malvaceae)</td>
<td>leaf</td>
<td>copper nanoparticles</td>
<td>MTT assay - CACO-2, HepG2, MCF-7</td>
<td>Hassaniel et al., 2019</td>
</tr>
<tr>
<td>46</td>
<td>Tribulus terrestris L. (Zygophyllaceae)</td>
<td>fruit</td>
<td>gold nanoparticles</td>
<td>MTT assay - ATCC-43504</td>
<td>Gopinath et al., 2016</td>
</tr>
<tr>
<td>47</td>
<td>Tridax procumbens L. (Compositae)</td>
<td>leaf</td>
<td>Methanol, ethanol, aqueous, chloroform, acetone, ethyl acetate</td>
<td>MTT assay - A549, MCF-7</td>
<td>Syed et al., 2020</td>
</tr>
<tr>
<td>48</td>
<td>Trigonella foenum graecum L. (Fabaceae)</td>
<td>seed</td>
<td>essential oil</td>
<td>MTT and NRU assay - HEP2, MCF-7, WISH, Vero</td>
<td>Al-Oqail et al., 2013</td>
</tr>
<tr>
<td>49</td>
<td>Viscum album L. (Santalaceae)</td>
<td>mistletoe</td>
<td>aqueous</td>
<td>MTT assay - HCC1937and HCC114, PA-TU-8902, DU145, NCI-H460</td>
<td>Weissenstein et al., 2014</td>
</tr>
<tr>
<td>50</td>
<td>Ziziphus nummularia Burm.f. (Rhamnaceae)</td>
<td>leaf</td>
<td>zinc oxide nanoparticles</td>
<td>MTT assay - HeLa</td>
<td>Padalia and Chanda, 2017</td>
</tr>
</tbody>
</table>

Other than plant aqueous or solvent extracts, essential oils and nanoparticles synthesized using plant extract also showed anticancer properties. Some essential oils showing anticancer activity are Cinnamomum cassia (Chang et al., 2017); Citrus sinensis (Yang et al., 2017); Rhizoma Curcumae (Zhong et al., 2018); Prunus cerasus cerry (Maragheh et al., 2019), etc. Some of the examples of metal nanoparticles showing anticancer property using different plant parts are silver nanoparticles synthesized using seed extract of Alpinia katsumadai (He et al., 2017), latex of Euphorbia antiquorum L. (Rajkuberan et al., 2019), leaf extract of Cynara scolymus (Erdogan et al., 2019), pulp extract of Abelmoschus esculentus (Mollick et al., 2019). Gold nanoparticles synthesized from peel extract of Citrus maxima (Yuan et al., 2017), Guazuma ulmifolia barksynthesized Ag, Au and Ag/Au alloy nanoparticles (Karthika et al., 2017), plant extract of Scutellaria barbata (Wang et al., 2019), rhizome of Zingiber officinale (Ascar et al., 2019).

Zinc oxide nanoparticles synthesized using flower extract of Nyctanthes arboristris (Jamdagni et al., 2018), fruit extract of Vaccinium arctostaphylos (Mohammadi-
Aloucheh et al., 2018), root extract of *Scutellaria baicalensis* (Chen et al., 2019).

This review summarizes some selected medicinal plants showing anticancer properties. *In vitro* studies have been done with promising results so they can be exploited for plant based anticancer drugs in the near future.

However, detailed studies have to be done on the structural characterization of the phytochemicals involved and their molecular mechanism of action has to be worked out especially using *in vivo* models. This may lead to the discovery of novel natural compounds which can act as anticancer agents with better therapeutic efficacy and minimal side effects.

Finally clinical trials can also be attempted which will yield effective, economic and safe natural anticancer drugs. Such screening programs are likely to yield some new compounds which may themselves act as drug molecules or excellent leads for designing and synthesizing new, novel compounds which can be used for cancer treatment. It will also help the researcher in selecting a promising medicinal plant for *in vivo* studies and hence hasten the speed of exploiting the nature for anticancer drugs.

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**References**


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