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REVIEW

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Role of phytochemicals as potential radioprotectants

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Abstract

Background: Ionizing radiations causes harm to living organisms and the rapid technological progress has increased human exposure to ionizing radiations enormously. Ionizing radiations come in contact with exposure from space radiations, nuclear war, and radiotherapy for cancer-like disease.

Main body of the abstract: There is a need for human beings against these effects of ionizing radiation due to lack of safe and effective radiation available so far, and the traditional medicines used from ancient times of different disease and protection against radiation. A systematic in vivo and in vitro study may use to identify a new lead compound as a radiation shielding agent. The radioprotective properties of plant and herbal extracts, as well as their radioprotective doses, are highlighted in this article. The outcomes of the in vitro and in vivo studies indicate that several botanicals such as *Gingko biloba, Centella asiatica, Ocimum sanctum, Panax ginseng, Emblica officinalis, Phyllanthus amarus, Piper longum, Tinospora cordifoila, Mentha arvensis, Mentha piperita, Syzygium cumini, Zingiber officinale, Ageratum conyzoides, Aegle marmelos* and *Piper betle* protect against radiation-induced lethality, lipid peroxidation, and DNA damage.

Short conclusion: The fractionation-guided evaluation may help to develop new radioprotectors for targeted activities.

Keywords: Radioprotection, Antioxidant, Cancer, Radiation therapy, *Aegle marmelos*

Background

Apart from medical and therapeutic purposes, the use of various types of radiation has increased dramatically in several areas of human life in recent decades, including agriculture, food processing and preservation, industry, nuclear power generation, aviation, space, electronics, communications, and warfare. As a result, while the greatest accomplishments in medicine, science, and technology help mankind live a better life (Hanumakumar et al. 2018), humans and other living species are increasingly exposed to various types of radiation, whether knowingly or unknowingly.

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The global burden of cancer is still increase and radiation treatment is an unavoidable option in the majority of cancer treatments in one stage or other (Ferlay et al. 2010). Radiotherapy inevitably involves exposure to normal tissues apart from targeting cancerous tissues. Radioprotection is an area of great interest due to its wide applications in planned radiotherapy as well as unplanned radiation exposure.

Various natural and synthetic compounds such as antioxidants, cytoprotective agents, immunomodulators, anti-inflammatory molecules, hematopoietic agents, vitamins, and DNA binding molecules have been evaluated extensively for their radio-protective potentials in both in vitro and in vivo models (Bala and Goel 2004; Liu et al. 2015; Maria et al. 2017; Molkentine et al. 2019). Random clinical trials on antioxidants, vitamins to prevent acute adverse effects of radiation indicate that the use of high doses of antioxidants as adjuvant therapy might compromise radiation treatment efficacy (Jena et al. 2010). As a result, there is no ideal synthetic radioprotector existing that fulfills all the requirements, such, no cumulative or irreversible toxicity, efficient long-term protection, stability for several years without reducing shelflife, and ease of administration. (Obrador et al. 2020).

Considering, the drawbacks associated with the currently available radioprotectors, plant-based radioprotectants are of great interest because plant-based formulations are used by 70% of people in the population for to treat a variety of minor to major ailments.

Plants are rich sources of polyphenols which include anthocyanins, flavonoids, stilbenes, tannins, lignins, etc. (Jagetia 2007a). Cells and tissues are equipped with endogenous enzymes e.g. superoxide dismutase (SOD), glutathione peroxidise (GPx), catalase, reduced glutathione (GSH), glutathione S transferase (GST) capable of neutralising free-radical induced cellular damage (Parihar et al.2007). These ionizing radiations damage cells, tissue organs by triggering a chain of molecular events within nanoseconds. i.e. DNA fragmentation resulting in the disruption of living cell or cell death. Ionizing radiation mainly ceases the "S phase" of mitosis of dividing cell (Hall and Giaccia 2006). They also promote the release of inflammatory cytokines including interleukin 1 (IL-1), and tumor necrosis factor á (TNF a) which act within the irradiated tissue as well as enter systemic circulation experiences cell killings (Brown and Wilson 2004; Rubin et al. 1995).

Once the level of reactive oxygen species increases above tolerable limits, exposure to high dose of ionizing radiation results in damage to the haematopoietic, gastrointestinal and central nervous systems depending on radiation dose (Hosseinimehr et al. 2006). Sepsis, opportunistic infections, neutropenia, and enhanced bacterial colonisation through the diseased gastrointestinal mucosa are the leading causes of death in the early stages of radiation-induced hematopoietic syndrome, due to reduced neutrophils and increased entry of bacteria across the denuded gastrointestinal mucosa. The situation is aggravate by thrombocytopenia and defects in the adaptive immune system (Dainiak 2002). The gastrointestinal barrier is damaged and high amounts of water and electrolytes are lost from the body, resulting in dehydration and bacteraemia (Hosseinimehr 2007) as given in Fig. 1.

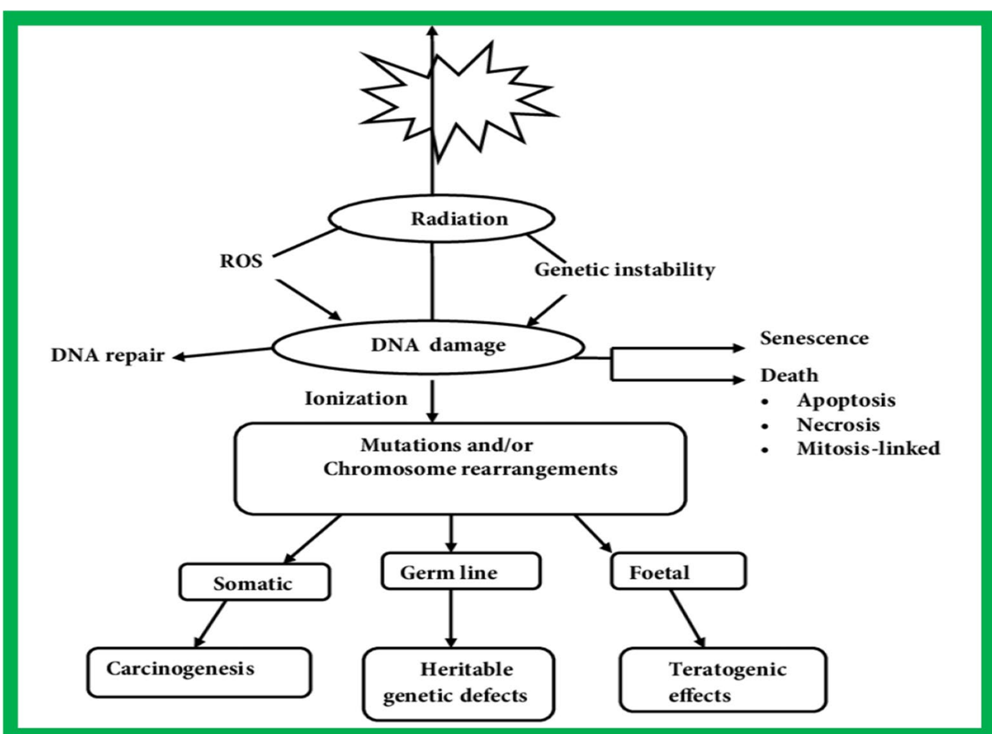


Fig. 1 Effect of radiation on the human body

Chemical compounds as radioprotectants

The efficacy of any radioprotector is expressed in terms of dose modifying factor (DMF) or dose reduction factor (DRF). DRF is evaluated by plotting the percentage survival at the end of 30 days against different doses of radiation (Patt et al. 1949).

$$\frac{\text{DMF Radiation LD50 in the presence of the protector}}{\text{DRF Radiation LD50 in the absence of protector}}$$

where LD50 is the lethal dose of radiation causing 50% of death in animals.

Main text

Naturally occurring radioprotectors

Amifostine is currently the only chemical drug approved by the FDA for protecting against the toxicity of radiotherapy in cancer patients. Similar to thiols, aminothiols, thiadiazoles, and benzothiazoles, the amifostine free radical scavenger is an organic thiol phosphate precursor and chemical radioprotectant. However, the efficacy of such chemical radioprotectors is restricted due to their high toxicity and associated side effects (Mun et al. 2018).

Plant is the best resource as radioprotective because there is a presence of chemical constituents that are responsible for antioxidant action, efficient, economically viable and clinically acceptable for human application. Many plants are rich sources of phytochemicals, flavonoids (quercetin, orientin, myricetin-flavonol, luteolin-flavone and (−)-epigallo catechingallate—flavanol, rutin, naringin, etc.), have been reported as potent antioxidants with radioprotective abilities (Benkovic et al. 2008; Lee et al. 2017) mention in Tables 1 and 2.

Polyphenols have an antioxidant activity that is activated by radiation. Polyphenols could up-regulate messenger RNA of antioxidant enzymes such as catalase, GSH transferase, GSHPx, superoxide dismutase (SOD) and hence reducing oxidative stress and repairing RNA damage (Faramarzi et al. 2021).

The plants and herbs may also suppress the activation of protein kinase C, mitogen activated protein kinase, cytochrome P-450, nitric oxide and several other genes that may be responsible for inducing damage after irradiation (Jagetia 2007b) as given in Fig. 2. A variety of plant-derived materials such as polysaccharides, lectins, peptides flavonoids and tannins have been reported to modulate the immune system with potent good immunomodulatory activity.

Given the urgent need for effective and safe medicinal resources and the broad range of circumstances in which radioprotectors are required, future efforts to develop natural radioprotectors remain great important.

Plants and herbs as radioprotectants

Curcuma longa (Haldi)

It is a perennial shrub of the Zingiberaceae family that can be found in almost all Indian states, but especially in Bengal, Mumbai, Andhra Pradesh and Tamil Nadu where it is cultivated for commercial reasons. Widespread research in the last decade in cell culture and rodents has shown that curcumin can sensitizes tumors to different chemotherapeutic agents. Likewise, evidence to demonstrates that this agent can sensitize a variety of tumors to γ-GR including glicoma, neuroblastoma, cervical carcinoma, epidermal carcinoma, prostate cancer, and colon cancer. Earlier research has shown that it down-regulates several growth regulatory pathways and precise genetic targets including genes for nuclear factor kappa-light-chain-enhancer of activated B cells, signal transducer and activator of transcription 3, cyclooxygenase-2, Akt (also known as protein kinase B), anti-apoptotic proteins, growth factor receptors, and multidrug-resistance proteins (Goel and Curcumin 2010) Curcumin been shown to safeguard normal organs against chemotherapy and radiotherapy-induced damage, while also acting as a chemosensitizer and radiosensitizer for malignancies in some cases. So Curcumin plays dual actions of radio protecting non-cancerous normal cells while radio sensitizing tumor cells.

It seems that the protective effects of the curcumin are facilitated through their ability to induce the activation and expression of antioxidant enzymes, directly quench free radicals, and inhibit p300 histone acetyl transferase (HAT) activity. These preclinical studies are designed to lead clinical trials to prove the potential of this age-old golden spice for treating cancer patients and radiation effects (Jagetia 2007b). As indicate, *Curcuma longa* (as shown in Fig. 3) has a beneficial radioprotective effect against radiation-induced oxidative stress in male rats by alleviating pathological disorders and modulating antioxidant enzymes (Nada et al. 2012).

Ocimum sanctum (Tulsi)

It is a Lamiaceae family herb that is extensively spread in tropical and mild temperate regions. Ocimum genus contains about 130 species of herbs and shrubs from the tropical regions of Asia (Bailey 1924; Upadhyay et al. 2015). In albino mice, an aqueous-ethanolic extract of *O. sanctum* was reported to have a radioprotective effect against gamma radiation. The optimal dose for protection has been reported to be 50 mg/kg body weight while the acute LD50 was 6 g/kg body weight. Ocimum flavonoid, orientin and FDA-approved amifostine were found to exhibit a similar radioprotection at the doses of 50 mg/kg body weight and 150 mg/kg body weight

Table 1 Traditional herbal plants showing therapeutic activities relevant to radioprotection

Sr. No	Biological source	Common name	Active compound	Radioprotective action	Dose	References
1	*Adhatoda vasica* (Acanthaceae)	Vasaka	Vesicine, vesicinone, betaine, vitamin C, b-carotene and vasakin	Irradiation showed significant protection in survival percentage and hematological parameters in mice. DRF 1.6	800 mg/kg p.o	Kumar et al. (2005)
2	*Aegle marmelos* (Rutaceae)	Bael	Skimmianine, luvangetin, psoralen, marmin, marmelide, aurapten, marmelosin, lupeol, aegelin, marmrsinin, eugenol, and coumarin	Provided protection against radiation-induced sickness and mortality in mice	15 mg/kg b.wt	Jagetia et al. (2004) and Jagetia and Venkatesh (2005)
3	*Allium cepa Linn* (Alliaceae)	Bulb onion	Allyl propyl disulfide,31,8-cineole	Administration of the dried bulb effective against X-irradiation	20 mg/kg b.wt	Arora et al. (2005)
4	*Allium sativum L.* (Alliaceae)	Garlic	Allicin, flavonoids, phenol	Radioprotective efficacy of aged garlic extract (S-allyl cysteine, S-allylmercapto cysteine, allixin and selenium) possess significant antioxidant and anticarcinogenic properties	1gm/kg b. wt./day p.o	Singh et al. (1995) and Gupta (1996)
5	*Aloe arborescens* (Liliaceae)	Indian aloe	Campesterol, stigmasterol, *β*-sitosterol	Extract protected mouse skin against soft x-irradiation by scavenging hydroxyl radicals and reducing alterations in enzyme activity	750 mg/kg p.o	Sato et al. (1990)
6	*Asparagus racemosus* (Liliaceae)	Shatavari	9,10-dihydro-1,5 dimehtoxy-8-methyl-2,7-phenanthrenediol, steroidal saponins, polysaccharides	Antioxidant effects of crude extract and a purified aqueous fraction of Asparagus racemosus against membrane damage induced by the free radicals generated during gamma radiation were examined in rat liver mitochondria and was effective	10 mg/ml on rat liver mitochondria	Kamat et al. (2000) and Verma et al. (2014)
7	*Centella asiatica* (Apiaceae)	Brahmi	Titerpene, flavonoid, phenolic acid, sterols, acetylenes	Aqueous extract protects Sprague Dawley rats against the adverse effects of low-dose ionizing radiation (2 Gy). Administered orally, provides total body protection in mice against sublethal (8 Gy) 60 Co gamma radiation	100 mg/kg b. wt; i.p.; single dose; -1 h	Sharma and Sharma (2002)
8	*Curcuma longa* (Zingiberaceae)	Haldi, Turmeric	Curcumin	Curcumin (diferuloylmethane) has been reported to render radioprotective effect	100 mg/kg p.o	Choudhary et al. (1999)

Table 1 (continued)

Sr. No	Biological source	Common name	Active compound	Radioprotective action	Dose	References
9	*Emblica officinalis* (Euphorbiaceae)	Amla	Tannins, alkaloids, quercetin, emblicanin A and B, and ellagotannin	EOE is effective in preventing gamma radiation- induced lipid peroxidation and protected mitochondrial SOD. It also prevents radiation-induced DNA strand breaks in a concentration-dependent manner	100 mg/kg p.o	Bhattacharya et al. (2006) and Singh et al. (2005)
10	*Ginkgo biloba* (Cycadaceae)	Living Fossils	Ginkgetin and Ginkgolides (A & B)	An ethanol (30%) extract of the dried leaf is reported effective when tested on a culture exposed to clastogenic factors from plasma of human subjects exposed to irradiation and on rat cerebellar neuronal cell culture against hydroxyl radical-induced apoptosis	100 µg/ml	Veerapur et al. (2009), Ni et al. (1996) and Emerit et al. (1995)
11	*Glycyrrhiza glabra* (Fabaceae)	Liquorice	Glycyrrhizin	70% methanolic extract protected rat microsomal membranes from gamma radiation-induced lipid peroxidation	100 µg/mL	Kovalenko et al. (2003)
12	*Mentha arvensis* (Lamiaceae)	Mint	Alkaloids, flavonoids, phenols, tannins, saponins, diterpenes, and monoterpenes	Pre-irradiation treatment with chloroform extract protected mice against gastrointestinal and bone marrow death (DMF: 1.2)	10 mg/kg i.p	Jagetia and Baliga (2002)
13	*Mentha piperita* (Labiatae)	Peppermint	Menthol	Radioprotective activity on the vital radiosensitive organs like testis, gastrointestinal and hemopoetic system in mice	1 g/kg p.o	Samarth and Samarth (2009) and Samarth (2007)
14	*Moringa oleifera* (Moringaceae)	Drumstick	Vitamin C	Leaf extract significantly reduced the percent aberrant cells in metaphase chromosomes to normal range by day 7 post-irradiation in mice	150 mg/kg single dose, pre-treatment i.p	Rao et al. (2001)

Table 1 (continued)

Sr. No	Biological source	Common name	Active compound	Radioprotective action	Dose	References
15	*Murraya koenigii* (Rutaceae)	Meethineem	Oxalic acid, glycosides, carbazole alkaloids, koenigin, resin,girinimbin, isomahanimbin, koenine, koenigine, koenidineandkoenimbine. Mahanimbicine, bicyclomahanimbicine, phebalosin, coumarine	The radioprotective effects of M. koenigii leaf extract were evaluated against 4 Gy γ-irradiation in the liver of mice. The leaf extract itself was effective for significantly increasing reduced glutathione (GSH) content and antioxidant enzyme levels in the liver as well as it reduced the radiation-induced decrease in lipid peroxidation, thus indicating the antioxidant properties of extract possibly contributing for radioprotection	100 mg/kg i.p	Iyer and Devi (2009)
16	*Myristica fragrans* (Myristicaceae)	Nutmeg	Myristicin, lignanand eugenol, abinene (15–50%), α-pinene(10–22%)and β-pinene(7–18%),with myrcene (0.7–3%), 1,8-cineole (1.5–3.5%), myristicin (0.5–13.5%), limonene (2.7–4.1%), safrole (0.1–3.2%) andterpinen4-ol(0–11%)	Protects testes of mice by inhibiting γ-radiation induced TBARS and increased the level of GSH	500 μg/ml p.o	Checker et al. (2008)
17	*Ocimum sanctum* (Lamiaceae)	Tulsi	Orientin, Vicenin	Compounds orientin and vicenin significantly increased mouse survival when administered 30 min before lethal whole-body γ irradiation Vicenin provided slightly higher protection (DMF: 1.37), compared to orientin (DMF: 1.30) in a murine model system. Reduced the chromosomal aberrations in the bone marrow of mice exposed to 2 Gy γ irradiation	50 μg/kg/i.p	Uma Devi et al. (1998) and Sudheer Kumar et al. (2003)
18	*Panax ginseng* (Araliaceae)	Ginseng	Ginsenosides, Polysaccharides	The water-soluble whole plant extract of ginseng provided the best protection against Co60 gamma radiation in C3H mice	300 mg/kg i.p	Lee et al. (2005)

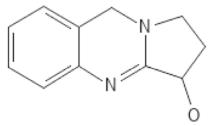
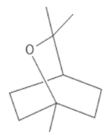
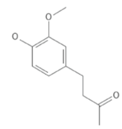
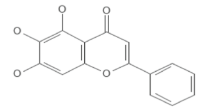
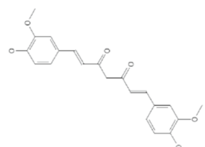
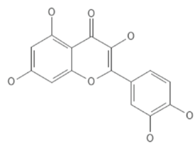
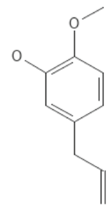
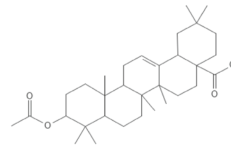
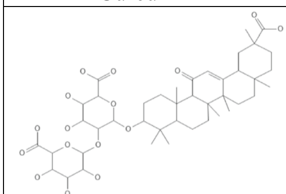
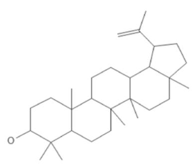
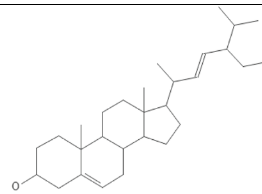
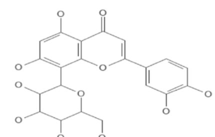
Table 1 (continued)

Sr. No	Biological source	Common name	Active compound	Radioprotective action	Dose	References
19	*Piper betle Linn* (Piperaceae)	Betel leaf	Chevibetol and allylpyrocatechol	Betel leaf has hydroxyls Superoxide radicals Scavenging property and also prevent radiation induced DNA strand breaks	50 μg/ml	Jagetia and Venkatesha (2006)
20	*Piper longum Linn* (*Piperaceae*)	Indian Long Pepper	Monoterpenes (Z) p-ocimene, a-pinene and b-pinene, most common sesquiterpenes identified, E-caryophyllene and germacrene D, have the E, E-farnesyl-PP as fundamental precursor and only two were originated from E, Z-farnesyl-PP reactions (a-copaene and d-cadinene)	The ethanolic extract of fruits was found to protect mice against the radiation-induced decline in WBC, bone marrow cells a-esterase positive cells and GSH	400 mg/kg, i.p	Sunila et al. (2005)
21	*Podophyllum hexandrum* (Berberidaceae)	Indian Podophyllum	Epipodophyllotoin, podophyllotoxin, aryl tetrahydro naphthalene lignans	*P. hexandrum* has been shown to act in a multifaceted manner and provide protection to haematopoietic, gastrointestinal, reproductive and central nervous system (CNS)	115 mg/kg i.p	Sajikumar and Goel (2003)
22	*Saccharum officinarum L* (Gramineae)	Sugarcane	Phenolics	Increasing the number of crypt/circumference effects and growth-promoting activity	42–55% fresh juice once on pBR322	Kadam et al. (2008)
23	*Spinacia oleracea L* (Chenopodiaceae)	Spinach	Carotenoids, Ascorbic acid, Flavonoids and P-Coumaric acid	The radioprotective efficacy of spinach is against Gamma radiation-induced oxidative stress and also due to antioxidant constituents present in Spinach	1100 mg/kg p.o	Gaikwad (2010)
24	*Syzygium cuminii (Linn.) Skeels* (Myrtaceae)	Jamun	Acetyl oleanolic acid, triterpenoids, ellagic acid, Jambolin	In vivo evaluation established its radioprotective activity where it was found to reduce radiation-induced sickness, gastrointestinal and bone marrow deaths. Treatment of human peripheral blood lymphocytes with leaf extract before gamma radiation (3 Gy) significantly reduced micronuclei induction	80 μg/ml	Tilak et al. (2003)

Table 1 (continued)

Sr. No	Biological source	Common name	Active compound	Radioprotective action	Dose	References
25	*Terminalia arjuna* (Combretaceae)	Arjuna	Baicalein	Terminaliaarjuna bark, the methanolic extract administered once on rat liver mitochondrial preparation showed the highest antioxidant and radioprotection activity	0.10% once on rat liver mitochondria	Tilak et al. (2003)
26	*Terminalia chebula* (Combretaceae)	Black myrobalan	Ascorbate, gallic acid and ellagic acid	Aqueous extract of a natural herb, Terminaliachebula was tested for its ability to inhibit gamma-radiation induced lipid peroxidation and damage to superoxide dismutase enzyme in rat liver mitochondria which shows a significant radioprotection by its antioxidant property	25–200 mg/ml p.o	Naik et al. (2004)
27	*Tinospora cordifolia* (Menispermaceae)	Guduchi	Cordifolioside-A, palmatine, tembetarine	A pure arabinogalactan polysaccharide, Genistein provides some protection against radiation-induced intestinal damage in mice. DMF: 1.16	5 mg/kg and 200 mg/kg p.o	Goel et al. (2004)
28	*Vitis labrusca* (Vitaceae)	Black grape juice	Trans-resveratrol	Inhibiting loss of body weight via reverse mandibular changes that interfere with normal feeding, attenuating the severity of osteoradionecrosis (ORN) as well as improving white and red blood cell counts	Fed ad libitum p.o	Freitas et al. (2017) and Andrade et al. (2011)
29	*Zingiber officinale* (Zingiberaceae)	Ginger	Zingerone	Reduced the severity of radiation sickness and mortality. The Zingiberofficinale treatment protected mice from gastrointestinal syndrome as well as bone marrow syndrome. The dose reduction factor was found to be 1.15	10 mg/kg i.p.,	Jagetia et al. (2003)

Table 2 Phytochemistry of some radioprotectives

 Vasicine	 Cineol	 Zingerone	 Baicalein
 Curcumin	 Quercetin	 Chevibetol	 Acetyl oleanolic acid
 Glycerrhizin	 Lupeol	 Stigmasterol	 Orientin

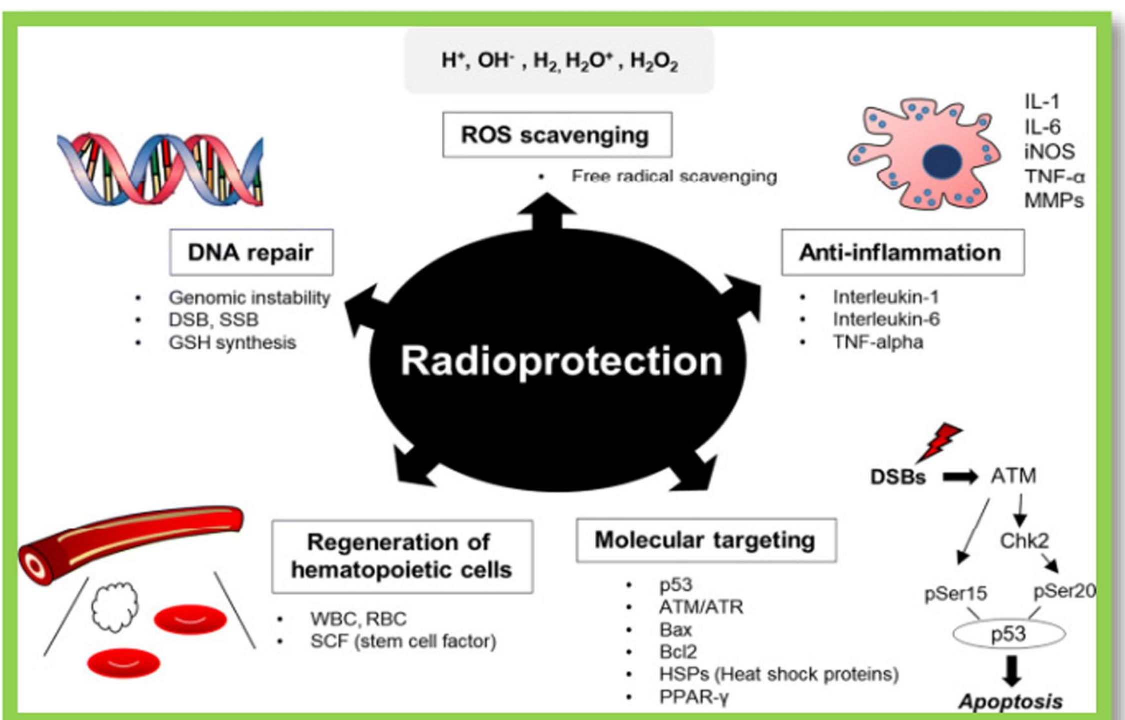


Fig. 2 Pharmacology of natural radioprotectants

Fig. 3 Curcuma longa

Fig. 4 Ocimum sanctum

respectively, upon irradiation with 2 Gy-gamma radiation whereas vicenin showed lesser activity (Uma Devi et al. 1999). Ocimum has been shown to have anti-melanoma and radioprotective properties in C57BL and Swiss Albino mice. The aqueous extract of Ocimum (as shown in Fig. 4) reduced tumor volume, increase in average body weight, and survival rate of mice. Radiation-induced chromosomal damage was modulated by Ocimum extracts, which caused an increase in reduced GSH level and GST activity. Radical scavenging activity has been demonstrated for both orientin and vicenin, and this appears to be one of the mechanisms of protection by these flavonoids (Baliga et al. 2012).

Zingiber officinale (Ginger)

It is an herbaceous perennial flowering plant, native to south China, spreading eventually to the Spice Islands and other parts of Asia and subsequently to West Africa. The rhizome of *Z. officinale* (as shown in Fig. 5) commonly known as ginger (Sunthi/Ardraka) has widely been used as a spice and condiment in different societies since antiquity. Numerous preclinical researches have revealed that ginger has chemopreventive and anticancer effects (Baliga et al. 2012). Preclinical studies carried out in the last decade have shown that ginger and its phytochemicals dehydrozingerone an zingerone possess radioprotective effects in laboratory animals and cultured cells *in-vitro*. Mechanistic studies have indicated that free radical scavenging, antioxidant, anti-inflammatory and anti-clastogenic effects may contribute towards the observed protection. Furthermore, research on tumor-bearing mice have also shown that zingerone selectively protects the normal tissues against the tumoricidal effects of radiation (Pereira et al. 2011).

Fig. 5 Zingiber officinale

Fig. 6 Ginkgo biloba

Ginkgo biloba (Bramhi)

Ginkgo biloba (Cycadaceae), a plant native to China, Japan and Korea, has been reported to stimulate endogenous antioxidants such as glutathione and attenuate oxidative stress.

A *Ginkgo biloba* extract, which is a mixture of flavonoids, heterosides and terpenes with antioxidant properties, has been shown to prevent mitochondrial aging by reducing oxidative damage. *Ginkgo biloba* (as shown in Fig. 6) extract is also useful in the treatment of cerebral disorders due to aging and hypoxia. Nearly 300 compounds are present in *Ginkgo biloba* including ascorbic acid, α-carotene, β-carotene, flavonoids, coumarins, catechins, ginkgolides, bilobalide, rhamnetin, γ-tocopherol to name a few, many of which individually in isolated form render radioprotective effects.

The extract of *Ginkgo biloba* protected brain neurons from oxidative stress. *G. biloba* leaf extract (30%) at a concentration of 100 μg/mL assayed in rat cerebellar neuronal cell culture, was active on neurons against hydroxyl radical-induced apoptosis (Arora et al. 2005).

Piper betle (Betel Leaf/Pan)

It is a tropical perennial evergreen plant that flourishes in the shadow belongs from Piparaceae family, native to central and eastern Malaysia and was taken into cultivation throughout Malaysia and tropical Asia. The radioprotective activity of Piper betel (as shown in Fig. 7) ethanolic extract (PE) has been studied using rat liver mitochondria and pBR322 plasmid DNA as two models in vitro systems (Bhattacharya et al. 2005). The extract effectively prevented gamma-ray induced lipid peroxidation as assessed by measuring thiobarbituric acid reactive substrates, lipid hydroperoxide and conjugated diene. Likewise, it prevented radiation-induced DNA strand breaks in a concentration dependent manner. The radioprotective activity of PE because of its hydroxyl and superoxide radical scavenging property along with its lymphoproliferative activity. The presence of phenolic components, which were separated and identified as chevibetol, was principally responsible for PE's radical scavenging activity (Bhattacharya et al. 2005).

Fig. 7 Piper betel

Conclusions

Due to the frequent exposure to ionizing radiation in many aspects of human life in particular areas relating to cancer radiation therapy, food preservation, agriculture, industry and power generation, there is a necessity to develop an effective and nontoxic radioprotector.

Thus, the increased use of nuclear radiation for human welfare requires the search for new, safe and inexpensive radioprotectors not only for workers who are responsible for testing or working with radiation in laboratories but also for the general public.

We are mention in this review *Curcuma longa, Ocimum sanctum, Zingiber officinale, Ginkgo biloba and Piper betle* this each plants consist of secondary metabolites like terpenoids, resins, triterpenoids which responsible for radioprotective action. The success of the development of radioprotective agents is increasingly and depended on the understanding of the molecular biology of radiation damage, cellular, tissue, organ responses to irradiation, the effect of co-morbid factors, and differences between tumor and normal cell biology, thus leading to an overall improvement in the efficacy of anticancer treatment. India has a traditional medicinal plant heritage, so it is possible to develop efficient, economically feasible and clinically efficiency and acceptable radioprotectors for human application of these resources. Most of these phytochemicals are used as immunomodulators in case of life-threatening diseases such as HIV-AIDS, corona, cancer, etc.

Thus, the current literature will bring more phytochemicals to develop new research into the radioprotection of suffering humanity and support the treatment of cancer.

Abbreviations

CNS: Central Nervous System; DMF: Dose Modifying Factor; DRF: Dose Reduction Factor; GPx: Glutathione Peroxidase; GSH: Catalase, Reduced Glutathione; GST: Glutathione S Transferase; HAT: Histone Acetyl Transferase; IL-1: Deoxyribonucleic Acid; ORN: Osteoradionecrosis; SOD: Superoxide Dismutase; TNF-α: Tumor Necrosis Factor α.

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Authors' contributions

The Concept was discussed by RJ while SC prepare the writing original draft of the article followed by RB with validation and data analysis, MC contributes with data collection, RG and IL checked the grammar and remove all the plagiarism then RJ Review and edit the article and finally SC done the formal analysis of the article. All the author read and approved the final manuscript.

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