Dilipkumar Pal *Editor*

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This book is dedicated to my parents

Late Nandalal Pal (Father)

and

Late Yamuna Pal (Mother)

Preface

In recent years, there has been an increasing interest in natural compounds as potential sources of anticancer agents. Among these natural compounds, seeds have been studied extensively for their pharmacological activities, including anti-proliferative, anti-inflammatory, antioxidant, and antitumor effects. Seed extracts have been found to contain a wide range of bioactive compounds, such as phenolic acids, flavonoids, lignans, alkaloids, and terpenoids, which have been reported to exert various pharmacological activities, including cancer prevention and treatment. This book, titled *Seeds: Anti-proliferative Storehouse for Bioactive Secondary Metabolites*, provides a comprehensive overview of the potential anticancer properties of various seeds. The book is divided into 30 chapters, each focusing on a specific seed or group of seeds and their anti-proliferative activity. The book begins with Chap. 1, which includes an introduction to seeds as a source of bioactive natural compounds, and discusses the potential health benefits and general adverse effects of seed extracts. Chapter 2 explores the relationship between seed life cycle and cell proliferation, highlighting the metabolic changes that occur during seed germination. It also discusses the potential mechanisms by which these metabolites may exert their anti-proliferative effects, including induction of apoptosis, cell cycle arrest, and inhibition of angiogenesis. Chapter 3 explores the potential of seed extracts as a source of natural anticancer agents and their market potential in the phyto-pharmaceutical industry. It also discusses the challenges and opportunities for commercialization of seed-derived anti-proliferative drugs, including extraction methods, product standardization, and regulatory requirements. Chapter 4 explores the potential of prune and date seeds as a source of natural anticancer agents. It discusses the bioactive compounds found in these seeds, such as polyphenols, flavonoids, and lignans, and their potential effects on cell proliferation, apoptosis, and cell cycle regulation. Chapter 5 discusses the potential anticancer properties of pumpkin seeds. The chapter explores the chemical composition of pumpkin seeds, the mechanisms of action underlying their anti-proliferative effects, and the potential use of pumpkin seed extracts in cancer prevention and treatment. Chapter 6 focuses on the role of grapefruit seed and its secondary metabolites in cancer prevention. The chapter discusses the chemical composition of grapefruit seeds and their extracts, and highlights the anticancer properties of these compounds. The chapter also explores the mechanisms of action underlying the anti-proliferative effects of grapefruit seed extracts and their potential use in cancer prevention and treatment.

Chapter 7 discusses the anti-proliferative activities of sesame and parsley seeds. The chapter explores the chemical constituents of these seeds, their potential health benefits, and their anticancer properties. Chapter 8 delves into the potential anticancer properties of Sunflower and Passiflora seeds, focusing on the secondary metabolites present within them. Sunflower and Passiflora seeds are rich sources of flavonoids, phenolic acids, and alkaloids, among other secondary metabolites, which have been found to possess anticancer properties. Chapters 9 and 10 explore the description, chemistry, and uses of bitter gourd and papaya seeds, with a focus on their anti-proliferative activities. The book aims to provide a comprehensive overview of the scientific evidence supporting the use of these natural plant units as potential therapeutic agents, and to highlight their potential as a source of new drug leads. Chapter 11 explores mango and guava seeds, studying their potential in preventing the proliferation of malignant diseases, while Chap. 12 focuses on apple and honey peach seeds, investigating their morphology, chemistry, anti-proliferative properties, and toxicity. Black plum seed and *Nigella sativa* (black cumin seed) are two such gifts of nature that have gained significant attention in recent years for their potential health benefits. Chapters 13 and 14 aim to provide an overview of the current state of research on these seeds, highlighting their morphology, chemistry, and anti-proliferative activities, respectively. Black plum seed is known for its potential in preventing the proliferation of cancer cells, while *Nigella sativa* has been extensively studied for its antioxidant and anti-proliferative properties. Chapter 15 focuses on watermelon seeds, which have been used for centuries in traditional medicine to treat a variety of ailments, including urinary tract infections and inflammation; recent research has also suggested that watermelon seeds may have a role in the prevention and treatment of carcinoma. In this chapter, the potential role of watermelon seeds in the prevention and treatment of carcinoma will be explored. We will examine the scientific evidence behind their anticancer properties, as well as the mechanisms through which they may exert their effects. Chapter 16 focuses on olive and winter jujube seeds, which contain a variety of bioactive compounds, including polyphenols, flavonoids, and triterpenoids, which may have anticancer properties. Some studies have found that olive seed extracts can inhibit the growth of cancer cells and induce apoptosis (programmed cell death), while winter jujube seed extracts have been shown to have antitumor effects in animal models. Chapter 17 provides a comprehensive description of the chemistry and uses of musk and hami melon seeds in the prevention and control of malignant diseases. The information provided in this chapter will be of great interest to researchers, healthcare professionals, and individuals seeking natural alternatives for cancer prevention and treatment.

Chapters 18–20 explore recent developments and future prospects of cotton seeds in controlling carcinoma and the role of secondary metabolites in this process, Carambola and Yunnan pomegranate seeds in controlling proliferative diseases, and provides insights into the effective treatment and control of anti-proliferative diseases with Orange and Kumquat seeds, respectively. These chapters provide detailed descriptions of the chemistry and uses of these plant seeds, as well as their potential as a source of natural compounds for controlling and treating cancer. They also present the latest research on the mechanisms by which these natural compounds exert their effects on cancer cells and the potential for future developments in this field. Chapters 21 and 22 explore the morphology and chemistry of two specific seeds in detail, as well as their potential use in cancer treatment. These chapters provide a comprehensive overview of the bioactive compounds present in these seeds and their anti-proliferative effects on various cancer cell lines. Additionally, the book highlights the potential mechanisms by which these compounds exert their anticancer effects. Chapter 23 explores the current state of scientific research on the role of the tamarind seed in cancer prevention and control. It discusses the active compounds found in the seed, including polyphenols, flavonoids, and alkaloids, and their potential mechanisms of action against cancer cells. Chapter 24 focuses on two such remedies: Chinese cabbage and anise seed. Both of these plants have been traditionally used in Chinese medicine for their various health benefits, including their potential anticancer properties. Chapters 25 and 26 focus on the role of pistachio, cashew, and almond seeds in preventing and treating abnormal cell growth, as well as the potential of litchi, salak, and strawberry seeds in producing anti-proliferation effects. These chapters will explore the various bioactive compounds present in respective seeds that have been linked to their anticancer properties and also delve into the possible mechanisms by which these seeds may exert their anti-proliferative effects, including antioxidant activity, anti-inflammatory properties, and the modulation of cell signaling pathways. Chapter 27 focuses on two medicinal plants, neem (*Azadirachta indica* L.) and hibiscus seed, which have been traditionally used in different parts of the world for their medicinal properties. Both neem and hibiscus seeds have been reported to have anti-proliferative properties, which make them potential candidates for the development of new drugs to combat cancer. Chapter 28 delves into the medicinal properties of chia, pear, and hawthorn seed, which have been used traditionally across various regions of the world. These seeds have been reported to possess anti-proliferative properties, indicating their potential as candidates for the development of novel drugs to fight cancer. By exploring the chemical makeup, pharmacology, and anti-proliferative effects of these plants, we aim to shed light on their promising role in cancer treatment. Chapter 29 explores the medicinal properties of Guabirobeira and Soursop seeds, traditionally used in South America. Both seeds have been found to possess anti-proliferative properties, making them potential sources of natural compounds for cancer treatment. The chapter covers their chemistry, morphology, and traditional uses in addition to their anti-proliferative effects. Chapter 30 focuses on the potential of camellia and lotus seed-derived subunits as novel therapeutic agents for the prevention and treatment of malignant diseases. The current state of research on the anticancer properties of these plants, including their mechanisms of action, challenges, and opportunities associated with the development of these plant-based subunits as anticancer drugs, including issues related to safety, efficacy, and regulatory approval, is discussed.

I would like to convey my sincere thanks to all the authors of the chapters for providing timely and valuable contributions. I specially thank the publisher Springer Nature Singapore Pte Ltd, Singapore, for giving this opportunity to publish this book and invaluable support in organization of the editing process. I specially thank **Priyanga Kabali** for her priceless support right through the beginning to the finishing point of this book. I gratefully acknowledge the permissions to reproduce copyright materials from various sources.

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Bilaspur, Chhattisgarh, India — Dilipkumar Pal

Contents

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About the Editor

Dilipkumar Pal (Born in W.B., India) PhD, M Pharm, Chartered Chemist, Post Doct (Australia), is a Professor in the Department of Pharmaceutical Sciences, Guru Ghasidash Vishwavidyalaya (A Central University), Bilaspur, C.G., India. He received his master's and PhD degree from Jadavpur University, Kolkata, and performed postdoctoral research as an "Endeavor Post-Doctoral Research Fellow" at the University of Sydney, Australia. His areas of research interest include "Isolation, structure elucidation and biological evaluation of indigenous plants," "Synthetic Chemistry," and "natural biopolymers." He has published 200 full research papers in peer-reviewed reputed national and international scientific journals, having good impact factor, and contributed 121 abstracts in different national and international conferences. He has written 1 book, 90 book chapters, and edited 10 books published by reputed international publishers. His research publications have acquired a highly remarkable cited record in Scopus and Google Scholar (H-Index: 59; i-10-index 146, total citations 13,581 to date). Dr. Pal, in his 24 years research-oriented teaching profession, received 15 prestigious national and international professional awards including Endeavour Research Fellowship Award-2010 by the Dept of Education, Employment and Workplace Relations (DEEWR), Govt of Australia; ISTE Rajalaxmi Memorial Best Technical College Teacher Award-2009 by Indian Society for

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Chapter 1
Introduction of Seeds as Sources of Bioactive Natural Compound(s), Effects on Health, and General Adverse Effects

Dilipkumar Pal, Padum Lal, and Amalesh Samanta

Abbreviation

AGE	Acute gastroenteritis
F. ananassa	*Fragaria ananassa*
OSA	Oral allergy syndrome
P. granatum	*Punica granatum*

1.1 Introduction

A seed is the embryo of a plant enclosed in a protective outer shell containing food stores. The process of seed formation is part of seed plants, which include gymnosperms and angiosperms. After fertilization of the embryo sac with pollen spermatozoa, the spores are zygotized by the product of mature ovules. Inside the seed, the embryo develops from the zygote and, before development ceases, grows to a certain size inside the mother plant. The cotyledons arise from the entire finger of the ovary. There has been significant progress in the reproduction and success of seed plants of gymnosperms and angiosperms compared to more primitive plants such as ferns, mosses, and liverworts, which do not have seeds and use water-dependent means for their reproduction. From forest grasslands in hot and cold climates, seed plants now predominate in crushed organic coals. The general meaning of the word "seed" is also the first, as stated above—everything that can be planted; for

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example, “seeds” of potatoes, corn, or sunflowers. In the “seeds” of sunflower and corn, the seed is sown enclosed in a shell or husk, and in potatoes—tubers. In flowering plants, the ovary forms and distributes the fruit containing the seeds. Many structures commonly referred to as “seeds” are dried fruits. Sunflower seeds are sometimes sold commercially; however, they are encased in a hard fruit shell that must be broken apart to produce the seed. Other modifications are found in different groups of plants; the so-called stone fruits (peaches, etc.) have hard fruits. The inner cork layer that is connected to and encloses the actual seed, like acorns or hazelnuts (Bewley et al. 2006). The first land plants arose about 468 million years ago and reproduced with the help of spores (McGhee 2013). The oldest seed plants were gymnosperms without seed ovaries, which arose between 416 and 358 million years ago (Bora 2010). From these early gymnosperms in the Carboniferous period, seed ferns originated, one of which produced a pair of ovaries to which bunches of branches were attached, probably used to protect the developing seed (Taylor et al. 2009).

Seeds are produced in several related plant groups, and methods of production differ from angiosperms (“attached seeds”) and gymnosperms (“naked seeds”). Some fruits have layers that are both hard and fleshy. Gymnosperms have not developed a special structure for the conclusion of spores, which begin “naked” growth in fragments of cones. However, some coniferous species cover the seeds with conical stems. Seed production in natural plant populations varies widely from year to year depending on weather conditions, pests, diseases, and internal cycles within plants, for example, forests consisting of low-leaved and small-leaved forests produce between 0 and about 5.5 million healthy pine seeds per hectare in 20 years (Bragg et al. 2016).

1.1.1 Seed Formation

Seed formation begins with the fusion of male and female gametes, a process known as fertilization. When the male and female gametes are fully mature, either fertilization or mating can occur. This is usually done in a double fusion process known as double fertilization. When a pollen grain lands on the stigma of a pistil, it germinates, releasing a pollen tube that travels down the style through the micropyle to the embryo sac, the core of the tube extending down from the top of the tube (Bean 1980). The tube nucleus soon thins out, but two pollen sperm enter the embryo sac, a diploid ($2N$) polar nucleus to form a triploid ($3N$) endosperm nucleus with a double sac of the upper ovum ($2N$) zygote, or fertilized egg. The process of fertilization is very important as it determines not only the formation of seeds but also the level of genetic diversity present in the zygote. In angiosperms, fertilization usually occurs spontaneously or by cross-pollination. The process of fertilization is very important as it determines not only the formation of seeds but also the level of genetic diversity present in the zygote. In angiosperms, fertilization usually occurs spontaneously or by cross-pollination (Andrews et al. 1977).

1.1.1.1 Self-Fertilization

Self-pollination occurs when pollen from the inflorescence of one flower is transferred to the stigma of the pistil of the same flower, resulting in fertilization. This often occurs with flowers that do not open until pollination and fertilization are complete (Leffler et al. 1977).

1.1.1.2 Cross-Fertilization

Cross-fertilization occurs when pollen from one flower falls on the pistil of another flower. Flowers can be on the same or different plants. Cross-pollination of most crops occurs in two main ways: by wind (anemophily) and by insects (entomophily). Unlike self-fertilization, where the offspring are genetically identical, cross-fertilization results in more heterogeneous offspring. This evolutionary approach creates populations of individuals that are better adapted to a wide range of environmental conditions (Leffler et al. 1977).

1.1.2 Asexual Reproduction in Plants

In addition to sexual reproduction, many plants can reproduce asexually. There are two types of asexual reproduction in plants: vegetative and apomixis. Vegetative propagation can be done by stolons, rhizomes, tubers, shoots, tubers, bulbs, or corms. Apomixis is the seed production and asexual reproduction of plants (Leininger and Urie 1964).

The main features of apomixis are:

1. Sexual reproduction is followed by asexual reproduction.
2. Occurs in parts of the plant that are normally associated with the sexual process (flower parts).
3. Eggs and spermatozoa occur without fusion cells.

There are two types of apomixis: vegetative reproduction and agamospermia. Vegetative reproduction (also called live birth) is the transformation of an ear into a leaf figure on the scales. Agamospermia is apomixis resulting from the formation of spores, which involves either meiosis (reduction of division), fertilization, or both. Agamospermia may be the result of random embryonic or gametophytic apomixis (Leffler et al. 1977).

The inductive embryo develops from a diploid (2*N*) germinal nucleus or integumentary tissue (sporophyte tissue). In gametophyte apomixis, the processes of meiosis or diplopia lead to the formation of uninfected embryo sacs (gametophytes) without meiosis. Fewer embryo sacs can also develop as a result of meiosis (Leininger and Urie 1964).

Diploid embryo sacs with apospory are formed by mitosis in the nucleus or the inner shell. The diploid embryo sac is formed by the mother cell of the megaspore. Embryos are formed from diploid eggs without fertilization as a result of the processes of parthenogenesis and pseudozygosity (Martin 1937).

With diploid pseudocyesis, pollination stimulation is necessary for the development of the endosperm, and the egg develops without fertilization; In diploid parthenogenesis, pollination is not required for embryo development. Haploid (IN) embryos are formed from haploid eggs by haploid parthenogenesis (Randolph 1936) (Fig. 1.1).

1.1.3 Development of Seed

Seed development can be explained by barley changes characteristic of most cereals. Barley endosperm develops in cells in which free nuclei are formed in the first few divisions of the primary endosperm nucleus. About 2 days after fertilization, the cell wall is formed, which begins with changes within the periphery of the endosperm, which then becomes aleuronic. With the early development of the endosperm, the embryo begins to grow and differentiate. However, its contribution to the overall seed morphology is overshadowed by the endosperm (Thompson 1933).

Cellular organelles—plastids, mitochondria, ribosomes, and Golgi complexes—become recognizable shortly after initial cell formation, followed by the endoplasmic reticulum. After about 3 weeks, the structure of the endosperm is completely dominated by starch and protein granules (Varner 1965).

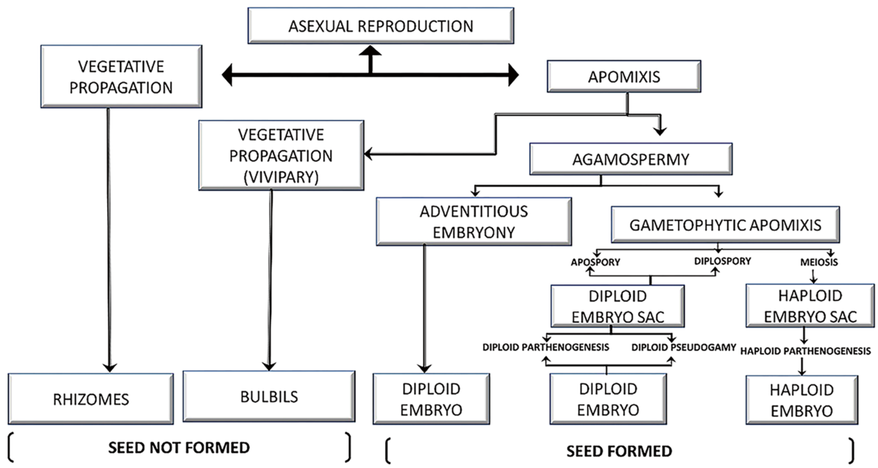


Fig. 1.1 Asexual reproduction in plants

1.1.3.1 Morphological Development

The morphological development of the seed occurs simultaneously with subsequent cytological, chemical, and mass changes. Such variations can also be detected when manipulating barley. The transformation from the reproductive meristem to the mature caryopsis growth (Briggs 1978).

1.1.3.2 Weight Changes Development

Shortly after sexual fusion, the developing seed begins to gain weight as a result of increased nutrient and water intake associated with rapid cell division and expansion. There is a sharp increase in dry weight. Immediately after fertilization, most of the dry matter is in the seed coat. However, after about 8 days, its weight exceeds the weight of the endosperm, which later becomes the main component of sperm (Sripling and Smith 1960).

1.1.3.3 Chemical Development

Immediately after fertilization, seed development begins and the seed becomes the main recipient (recipient) for assimilation within the plant. The seed production process consists of three main steps. The first stage occurs when seed growth reaches 80%. It is characterized by multicellular division and growth and a sharp increase in the mass of seeds due to the feeding of the mother plant by the fungus. The second stage occurs when the cord is damaged and the seed is separated from the mother plant. At this point, the seeds reach their maximum dry weight and quality, which is called the physiological maturity stage. In the third stage, after physiological maturity, the seeds become drier. This stage is affected by various weather conditions such as rainfall, high temperature, and exposure to field pathogens that increase or decrease seed moisture and seed quality; eventually, the seeds reach fruitful maturity, i.e., humidity (about 15–20%), at which mechanical storage of seeds is possible (Peet and Kramer 1980).

In monocot seeds, starch is the main carbohydrate in the endosperm and the whole seed. The carbohydrate content increases rapidly as the endosperm develops, partly at the expense of the shell pericarp tissue, where it decreases somewhat.

The seed of an angiosperm (flowering plant) has three genetically distinct components:

1. The embryo formed from the zygote.
2. The endosperm, which is usually triploid.
3. The maternal tissue of the ovum.

Seed development begins with double fertilization, in which two male gametes fuse with the egg and nucleus to form the primary endosperm and zygote. Immediately after fertilization, the zygote is mostly inactive, but the primary endosperm rapidly divides to form the endosperm tissue. This tissue is the food that the young plant will eat until it develops roots after sprouting (Martin 1946).

1.1.3.4 Ovule

As the ovules develop, size often influences the final seed size. Plants typically lay their eggs in four forms: the most common form is called the anatropous, which is curved. Orthotropous ovules are straight, and all parts of the ovule are arranged in long rows, forming a curved seed. The campylotropous ovule has a curved megagametophyte that often gives the seed a compact "C" shape. The form after ovulation is called amphibious disease, and the ovary is partially everted and turns 90° on the stem. In most flowering plants, the zygote's first division is oriented obliquely concerning the long axis, which determines the polarity of the embryo separated from the micropyle (Raven et al. 1981).

After fertilization, the oocytes turn into seeds. The ovary is made up of several components:

1. Flagellum (funiculus, funiculi) or seed stalk that connects the ovary to the placenta and hence to the wall of the ovary or embryo, the pericarp.
2. The megasporangium's remnant and the ovary's main site where the megagametophyte, the nucellus, develops.
3. Micropyle, a small pore or opening in the upper part of the intestine of the ovary, into which the pollen tube normally enters during fertilization.
4. Chalaza, the base of the ovary, opposite the micropyle where the mantle and nucleus fuse together (Kigel 2000).

1.1.3.5 Embryo

There are two distinct regions within the seed coat in endosperm seeds: the upper, larger endosperm and the lower, smaller embryo. An embryo is a fertilized egg, an immature plant from which, under the right conditions, a new plant develops. In the follicle of the embryo or seed leaf in one sac, two follicles are almost all double; in gymnosperms, there are two or more. In cereal fruits (caryopses), a monocotyledonous plant has a thyroid shape and is therefore called a scab. The scutellum is tightly pressed against the endosperm, allowing it to suck up food and pass it on to the growing parts. Fruit pigments are thin, straight, curved, and curly (Filonova et al. 2000).

The main elements of the embryo are: (1) The cotyledons are attached to the axis of the embryo. (2) A precise incision was made directly over the point where it was attached. (3) The buds, tip, apex, and wings are similar because young leaf cells are present and form shoots when germinated. (4) The cotyledon is the stem-root transition zone that connects the cotyledons and rays to the cotyledon axis below the point of attachment of the cotyledons. (5) The root end hypocotyl grows on the primary root (Filonova et al. 2000).

1.1.3.6 Seed Coating

The seed coat develops from the maternal tissue, the mantle, which initially surrounds the ovule. In a mature seed, the seed coat can be as thin as paper (such as peanuts), denser (such as thick and hard in acacia and coconut), or as fleshy as pomegranate sarcotesta. Depending on the development, the seed coat is prickly or monoecious. Bitegmal seeds form a testis from the outer shell and elytra from the inner shell, while unisexual seeds have only one shell. Usually, parts of the testes or elytra form a strong protective mechanical layer. The mechanical layer can prevent water penetration and germination. Barriers may include the presence of lignified sclereids (Sinauer Associates, Inc. Publishers 2014).

The outer shell consists of several layers, usually four to eight, consisting of three layers: (a) the outer epidermis, (b) the outer pigmented area containing tannins and starch, containing two of the five layers, and (c) the inner layer (Plant anatomy term seed coat epidermis 2014). The epidermal endothelium is derived from the inner epidermis of the endothelium, an outgrowth from the outer surface of the endothelium. The endothelium comes from the inner epidermis of the brain, and the outer layer of the testis is called the ectoderm from the outer surface of the brain. An exotesta may be one or more rows of elongated palatine-like cells (Fabaceae), hence the “palisade exotesta” (Rudall 2020).

1.1.4 Seed as a Source of Natural Bioactive Compounds

Seeds are often found as remnants of the agro-industrial complex (Veronezi and Jorge 2012). However, over the years, studies have shown that various plants’ seeds contain many bioactive components. As a recent PubMed shows, there is a growing enthusiasm for research on the polybiological activity and health benefits of these vegetable oils. Seed oils extracted from various plants such as gourd, bitter melon, Kalahari melon, kenaf, rosella, hemp, eruca, *Alsodaphni andersoni, Eucomia aluminides, Garcinia xanthochymus* are rich sources of polyunsaturated fatty acids and antioxidants such as tocols, bioflavonoids, and phytosterols (Chaikul et al. 2017). These vegetable oils are extracted in various ways using mechanical, chemical, or solution techniques and ultracritical liquid extraction techniques. The mechanical screw press method is widely used for vegetable oil extraction due to its simplicity and ease of operation (Bhuiya et al. 2015). It is necessary to ensure its functional properties and use with fatty acids, tocopherols, phospholipids, triacylglycerols, sphingolipids, and sterols in the oil mainly for its fatty acid components. Sources and biological activity are discussed in this chapter (Matthaus 2012) (Table 1.1).

Table 1.1 Bioactive compounds of some seed

Family name	Plant name	Common name	Bioactive compounds	Uses	References
Amaranthaceae	*Amaranthus cruentus*	Amaranth	α-, β-, γ-, δ-tocopherols, 24-methylenecholesterol, campesterol, stigmasterol, β-sitosterol, Δ5-avenasterol, Δ7-avenasterol, Δ7-stigmasterol, α-spinasterol, citrostandienol, cycloartenol	Anthelmintic activities, antifungal and antimicrobial effect, antiviral effect, antiosteoporosis effect, hypolipidemic effect, antidiabetic effect, hepatoprotective activity, cytotoxic activity	Ogrodowska et al. (2014)
Annonaceae	*Annona muricata*	Soursop	Fatty acids, α-,γ-tocopherols, carotenoids, campesterol, stigmasterol, β-sitosterol, epicatechin, *p*-coumaric acid	Anticancer activity, anticonvulsant activity, antidiabetic and hypolipidemic activity, anti-inflammatory and anti-nociceptive activity, and antioxidant activity	Navaratne and Subasinghe (2014)
Apocynaceae	*Hancornia speciosa* var. *pubescens*	Mangaba	Fatty acids, α-tocopherols, carotenoids, β-sitosterol, stigmastanol	Antidiabetic agent, as an antihypertensive agent for the treatment of obesity, anticancer, insecticidal action	Silva and Jorge (2016)
Asteraceae	*Arctium lappa*	Burdock	Arctin, arctigenin, artignan E	Antidiabetic effects, antioxidant and anticancer effects	Kothari (2013)
	Helianthus	Sunflower	Sesquiterpene lactone, diterpene, flavonoids	Antidiabetic, anticancer, anti-inflammatory activity, antioxidant	Stoia and Oancea (2013)
Boraginaceae	*Borago officinalis*	Borage	γ-,δ-tocopherols, β-sitosterol, Δ5-avenasterol, gramisterol, citrostandienol, cycloartenol	Multiple sclerosis, diabetes, heart disease, arthritis, and eczema	Czaplicki et al. (2011)
Brassicaceae	*Arabidopsis thaliana*	Arabidopas	α-,γ-tocopherols	Plant science, genetics and evolution, anticancer	Kothari (2013)
	Eruca sativa	Arugula	Allyl isothiocyanate, phenylethyl isothiocyanate, sulforaphane	Antioxidant, antiplatelet, antithrombotic, anticancer, and antimicrobial	Sanad and Mabrouk (2016)
Cannabaceae	*Cannabis sativa*	Hemp	Palmitic acid, stearic acid, oleic acid, linoleic acid, γ-linolenic acid, α-linolenic acid, eicosenoic acid, behenic acid	Diabetic metabolic syndrome, obesity, antioxidant, and neuroprotective	Da Porto et al. (2015)

Family name	Plant name	Common name	Bioactive compounds	Uses	References
Caricaceae	*Carica papaya*	Papaya	Fatty acids, α-,β-tocopherols, carotenoids, campesterol, stigmasterol, β-sitosterol	Used to treat cancer, wound healing, skin aging, periodontal disease, Alzheimer's disease, diabetes, and inflammation	Silva and Jorge (2016)
Combretaceae	*Combretum kraussii*	Forest bushwillow	Combretastatin B5	Wound heling anodyne, tonic and appetite stimulant	Kothari (2013)
Cucurbitaceae	*Cucurbita moschata*	Pumpkin	Fatty acids, α-,γ-tocopherols, carotenoids, stigmasterol, β-sitosterol, stigmastanol, salicylic acid	Antibacterial, antitumor, anti-inflammatory, and antihypertensive effects	Patel (2013)
	Cucumis melo var. *inodorus*	Melon	Fatty acids, α-,γ-tocopherols, carotenoids, β-sitosterol	Antioxidant, anti-inflammatory, antidiabetic	Silva and Jorge (2016)
	Citrullus lanatus	Watermelon	Lycopene, β-carotene, vitamins (B, C, and E), minerals (K, Mg, Ca, and Fe), amino acid (citrulline), phenolics	Urinary tract infections, bedwetting, ascites and kidney stones, alcohol poisoning, high blood pressure, diabetes, diarrhea	Choudhary et al. (2015)
Ericaceae	*Vaccinium corymbosum*	Blueberry	Fatty acids, carotenoids, tocopherols, phenolic content	Antioxidant, antidiabetic, anticancer	Parry et al. (2005)
Fabaceae	*Butea parviflora*	Bastard teak	Oleic acid, linoleic acid, palmitic acid, behenic acid	Antioxidant, anticancer	Kaki et al. (2016)
Juglandaceae	*Juglans regia*	Walnut	α-, β-, γ-, δ-tocopherols, campesterol, stigmasterol, β-sitosterol, Δ5-avenasterol, citrostandienol, cycloartenol	Coronary heart disease, diabetes, antioxidant, antimicrobial, and neurological disorders	Czaplicki et al. (2011)
Lamiaceae	*Thymus vulgaris*	Thyme	Linoleic acid, oleic acid, stearic acid, palmitic acid, γ-tocopherol	Antitussive, antibronchodilator, antispasmodic, anthelmintic, carminative, and diuretic properties	Assiri et al. (2016)

(continued)

Table 1.1 (continued)

Family name	Plant name	Common name	Bioactive compounds	Uses	References
Linacea	*Linum usitatissimum*	Linseed	α-, γ-, δ-tocopherols, campesterol, stigmasterol, β-sitosterol, Δ5-avenasterol, cycloartenol, 24-methylene cycloartenol	Anticancer, antioxidant, antimicrobial, anti-inflammatory, antiobesity, antidiabetic, antidiarrheal, antimalarial, hepatoprotective, antiarrhythmic	Czaplicki et al. (2011)
Lythraceae	*Punica granatum*	Pomegranate	Phytosterols, tocopherols	Antioxidant activity, antimicrobial, antibacterial activity, anti-inflammatory, and anticancer activity	Durdevic et al. (2018)
Malvaceae	*Hibiscus cannabinus*	Kenaf	Vitamin E, β-sitosterol, alpha-linolenic acid (ALA)	Blood and throat disorders, bilious conditions, anticancer, antioxidant	Yoshime et al. (2016)
	Hibiscus sabdariffa	Roselle	Linoleic/oleic acid, fatty acids, β-sitosterol, campesterol, δ-5-avenasterol, cholesterol	Anticancer, blood pressure, lipid-lowering effects, antioxidant	Al-Okbi et al. (2017)
Myrtaceae	*Psidium guajava*	Guava	Fatty acids, α-,β-,γ-tocopherols, carotenoids, β-sitosterol, stigmastanol, *p*-coumaric acid, salicylic acid, quercetin	Anticancer, antidiabetic activity, antioxidant activity, antidiarrhea activity, antiobesity	Silva and Jorge (2016)
Pedaliaceae	*Sesamum indicum*	Sesame	γ-tocopherols, campesterol, stigmasterol, β-sitosterol, Δ5-avenasterol, Δ7-avenasterol, sesamin	Treatment of hepatitis, diabetes, migraine, analgesic, and anticancer effect	Kothari (2013)
Rosaceae	*Rubusursinus idaeus*	Boysenberry	Fatty acids, carotenoid, tocopherols, phenolic contents	Anti-inflammatory, anticancer, antioxidant, hypolipidemic, and hypoglycemic	Parry et al. (2005)
	Fragaria ananassa Duchesne	Strawberry	Fatty acids, γ,α-tocopherols, carotenoids, β-sitosterol, stigmastanol, caffeic acid	Antioxidant activity, antimicrobial, antibacterial activity, anti-inflammatory, anti-allergenic	Silva and Jorge (2016)
	Rubusidaeus	Red raspberry	Fatty acids, carotenoid, tocopherols, phenolic content	Anti-inflammatory, anticancer, antioxidant, treat wounds, diarrhea, colic pain, and as a uterine relaxant	Parry et al. (2005)

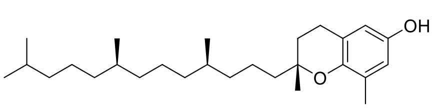
Family name	Plant name	Common name	Bioactive compounds	Uses	References
Rutaceae	*Fortunella margarita* Swingle	Kumquat	Fatty acids, carotenoids, campesterol, stigmasterol, β-sitosterol, *p*-coumaric acid, salicylic acid, quercetin	Anti-inflammatory, anticancer, antioxidant, treat wounds	Silva and Jorge (2016)
	Citrus sinensis	Orange	Fatty acids, α-tocopherols, carotenoids, campesterol, β-sitosterol, salicylic acid	Treatment of constipation, cramps, colic, diarrhea, bronchitis, tuberculosis, cough, cold, obesity, menstrual disorder, angina, hypertension, anxiety, depression, and stress	Silva and Jorge (2016)
	Citrus medica	Citron	Fatty acids, α-tocopherols, campesterol, β-sitosterol, *p*-coumaric acid, salicylic acid, quercetin	Anti-catarrhal, capillary protector, antihypertensive, diuretic, antibacterial, antifungal, anthelmintic, antimicrobial, analgesic, anticancerous, antidiabetic, estrogenic, antiulcer, cardioprotective	Silva and Jorge (2016)
	Rubus sp.	Marion berry	Fatty acids, carotenoid, tocopherols, phenolic contents	Anti-inflammatory, anticancer, antioxidant	Parry et al. (2005)
Solanaceae	*Solanum lycopersicum*	Tomato	Fatty acids, γ-tocopherols, carotenoids, β-sitosterol, stigmastanol, *p*-coumaric acid, salicylic acid	Antimutagenic activity, hypertension, hypercholesterolemia, diabetes, radioprotective activity, inflammation, antimicrobial, anticancer, anti-inflammatory activity	Silva and Jorge (2016)
Theaceae	*Camellia sinensis*	Tea	Saponin, oleiferasaponin A_1	Anticancer, antimutagenic activity, antimicrobial, antiviral activity, anti-schistosomiasis	Wang et al. (2017)
Vitaceae	*Vitis labrusca*	Grape	Fatty acids, α-,β-,γ-tocopherols, carotenoids, campesterol, stigmasterol, β-sitosterol, catechin, caffeic acid		Freitas et al. (2017)

1.1.4.1 *Amaranthus cruentus*

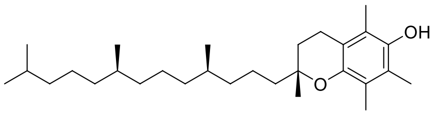
Amaranthus cruentus belongs to the order Caryophyllales, family Amaranthaceae, subfamily Amaranthoideae, and genus amaranth (Montoya-Rodríguez et al. 2015). *Amaranthus cruentus* is an annual herbaceous plant that propagates only by seeds and has a short growing season of 4–6 weeks (Makinde et al. 2010). It has a large and strong taproot. Thick stems are usually straight and branched, 0.1–2.0 m high, banded, reddish. The leaves are spirally arranged, simple, without stipules, varying in shape from ovate to unpaired ovate. The surfaces of leaves and stems are covered with fine hairs. Many unisexual flowers are green and produce finger-like spikes with long, dense terminal spikes and axillary spikes below. The last spike usually relaxes. Tepals 5-lanceolate, acuminate, 2–3 mm long, with long acuminate tips, making the inflorescence distinctly spiny (Śmigerska 2016).

1.1.4.1.1 Chemical Constituent

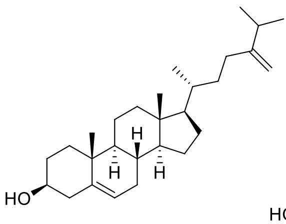
Amaranth seeds contain about 1% inositol, small amounts of glucose, fructose, and other monosaccharides and disaccharides such as raffinose, sucrose, maltose, and stachyose. Raffinose is higher than wheat but lower than maize (Januszewska-Jóźwiak and Synowiecki 2008). The content of low molecular weight carbohydrates in *A. cruntus* includes fructose, glucose, inositol, and maltose. They also contain α-, β-, γ-, δ-tocopherols, 24-methylenecholesterol, campesterol, stigmasterol, β-sitosterol, Δ5-avenasterol, Δ7-avenasterol, Δ7-stigmasterol, α-spinasterol, citrostandienol, and cycloartenol (Wolosik and Markowska 2019).



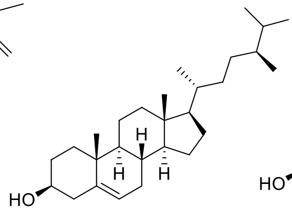
Delta-Tocopherol



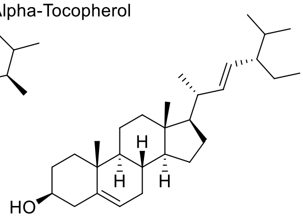
Alpha-Tocopherol



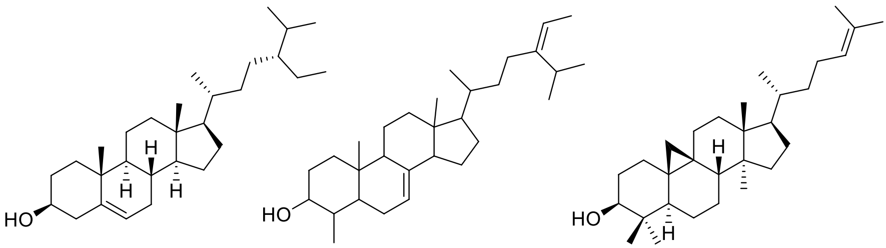
24-methylenecholesterol



Campesterol



Stigmasterol



Beta-Sitosterol Citrostandienol Cycloartenol

1.1.4.1.2 Uses

The seeds, seed oil, and leaves of amaranth are used for health benefits such as lowering blood pressure, cholesterol, and weight, boosting immunity, treating anemia, gastrointestinal disorders, antioxidant properties, and anti-inflammatory properties, anthelmintic activities, antifungal and antimicrobial effect, antiviral effect, antiosteoporosis effect, hypolipidemic effect, antidiabetic effect, hepatoprotective activity, and cytotoxic activity (Mroczek 2015).

1.1.4.1.3 General Adverse Effects

Amaranth can cause diarrhea and abdominal pain in people with lysine protein intolerance. Also, another side effect of lysine is that it increases the absorption of calcium by the body and is detrimental to generating the amount of calcium in the body, so you should not consume large amounts of calcium and lysine at the same time. Eating too much grain amaranth can be potentially dangerous for people with hypoglycemia due to its ability to lower insulin levels (Olawoye et al. 2021).

1.1.4.2 *Annona muricata*

Annona muricata L., commonly known as soursop, Graviola, soursop, papaya, and headdress, is a member of the Annonaceae family, which includes about 130 genera and 2300 species (Mishra et al. 2013). It is native to South America and currently widely distributed in tropical and subtropical parts of the world in India, Malaysia, and Nigeria (Adewole and Caxton-Martins 2006). Muricata is a terrestrial erect evergreen tree 5–8 m high with a spreading rounded crown. It is a tree with large, shiny, dark green leaves that produces large, heart-shaped, green, edible fruits 15–20 cm in diameter (Ribeiro de Souza et al. 2009).