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Revisão

Sources of alpha-, beta-, gamma-, delta- and epsilon-carotenes: A twentieth century review

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RESUMO: "Fontes de alfa-, beta-, gama-, delta-, e epsilon-carotenos: Uma revisão do século XX". Uma vez que os humanos não podem sintetizar carotenóides, dependem exclusivamente da dieta como fonte desses micronutrientes. Tem sido afirmado que eles podem aliviar doenças crônicas, tais como cânceres. O presente artigo constitui uma revisão global da literatura científica sobre plantas e outros organismos que biossintetizam carotenóides, que incluem as séries alfa-, beta-, gama-, delta-, e epsilon-carotenos. Os resultados das listas de pesquisa da literatura mostram mais de quinhentas fontes.

Unitermos: α-Caroteno, β-caroteno, γ-caroteno, δ-caroteno, ε-caroteno, carotenóides, câncer, revisão.

ABSTRACT: Since humans cannot synthesize carotenoids, they depend upon the diet exclusively for the source of these micronutrients. It has claimed that they may alleviate chronic diseases such as cancers. The present communication constitutes a global review of the scientific literature on plants and others organisms that biosynthesize carotenoids, which include the series alpha-, beta-, gamma-, delta- and epsilon-carotenes. The results of the literature survey lists more than five hundred sources.

Keywords: α-Carotene, β-carotene, γ-carotene, δ-carotene, ε-carotene, carotenoids, cancer, review.

INTRODUCTION

The carotenoids constitute the largest class of naturally occurring pigments and have attracted the attention of chemists and biologists since 1831, when an yellow coloring agent named β-carotene was isolated from the carrot (*Daucus carota*) for the first time. Many treatises have been devoted to the almost 1000 *cis-trans* carotenoid isomers characterized in nature (Britton, 1984, 1985, 1986, 1989, 1991). Most have 40 carbon atoms, less than 10% are hydrocarbons, most have oxygen functions, and some are conjugated with sugars and other molecules. Major provitamin A in mammals are β-carotene and α-carotene, although γ-carotene and approximately 50 other carotenoids also show some nutritional activity. Carotenoids are synthesized in plants from acetyl-coenzyme A by a series of well-defined condensations reactions. The synthesis of carotenoids does not occur in animal tissue; however, when those pigments are ingested in the diet, the animals deposit or modify their basic structure (Olson, 1989).

Most cancers that are common nowadays are not caused by the products of modern industry, but by the lifestyle, especially the diet. The scientific literature is consistent in evidences that it is possible to reduce the risk of acquiring some types of cancer by eating a variety of vegetables and fruits (Steinmetz & Potter, 1996; Federmann & Federmann, 2000). The types of vegetable or fruit that most often appear to be protective against cancer are raw vegetables, followed by allium, carrots, green vegetables, cruciferous vegetables, and tomatoes. Substances present in vegetables and fruit that may help protect against cancer, and their mechanisms, include, allium compounds, flavonoids, protease inhibitors, saponins, phytosterols, carotenoids, vitamins, selenium and dietary fiber. Increment in vegetable and fruit consumption, include also benefits against cardiovascular disease, diabetes, stroke, obesity, diverticulosis, and cataracts (Peto et al., 1981).

In a previous paper this research group has reviewed crude plant extracts and chemically defined molecules with potential antitumor activity for mammary (Moura et al., 2001), cervical (Moura et al., 2002) and ovarian neoplasias (Silva et al., 2003), as inhibitors of HMG CoA reductase (Gonçalves et al., 2000), central analgesic activity (Almeida et al., 2001), employed in

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prevention of osteoporosis (Pereira et al., 2002), for the treatment of Parkinson's disease (Morais et al., 2003), with antileishmanial (Rocha et al., 2005), hypoglycemic (Barbosa-Filho et al., 2005), antiinflammatory activity (Falcão et al., 2005, Barbosa-Filho et al., 2006a), inhibitors of the enzyme acetylcholinesterase (Barbosa-Filho et al., 2006b), inhibitors of the angiotensin converting enzymes (Barbosa-Filho et al., 2006c), giardicidal (Amaral et al., 2006), and antileprotic activity (Barbosa-Filho et al., 2007).

This work aims at presenting the main natural sources of carotenoids, which include the series α-, β-, γ- , δ- and ε-carotene.

MATERIAL AND METHODS

An extensive literature search was carried out using the Chemical Abstract, Biological Abstract and in the data bank of the University of Illinois in Chicago - NAPRALERT (Acronym for NAtural PRoducts ALERT), updated to March 2000.

The keywords used (in various combinations) in the search were: plants natural products, carotenoids, alpha-, beta-, gamma-, delta- and epsilon-carotene. The references found in the search were then consulted.

Consultation of various types of literature resulted in the elaboration of a list of occurrence of alpha-, beta-, gamma-, delta- and epsilon-carotene in plants and other organisms. For details the original references should be consulted.

Source of carotenoids

Carotenoids are found almost everywhere in nature, but particularly among organisms that bask in the sun. Those interesting compounds, most of which show a yellow to red color, have attracted the attention of chemists and biologists since at least the early 1800s. The colored compounds in plants and microorganisms were extracted and purified, and in time their structures were determined. Many treatises have been devoted to these compounds (Isler, 1971) the most comprehensive revision were presented by Briton (Britton, 1984, 1985, 1986, 1989, 1991).

We encountered 690 carotenes reported in the literature, 477 are found to be β-carotene, 144 α-carotene, 43 γ-carotene, 22 ε-carotene and 4 δ-carotene, so 310 are found in Dicotyledons, 122 Monocotyledons, 76 algae, 44 Gymnosperms, 22 ferns and allies, 8 lichens, 5 fungi, 4 bacteria and 2 insects.

Orange vegetables, such as carrots, sweet potatoes, winter squash, and pumpkin, are relatively rich sources of β-carotene, as are some fruits, including papaya, mango and cantaloupe. Because of the interest of carotenoids in preventing many types of cancer, it is also important to know which specific plants keep the greatest number of them. We found that *Calendula arvensis, C. officinalis, Citrus paradise, Daucus carota* and *Diospiros kaki* biosynthesize α-, β-, γ- δ- and ε-carotenes (Table 1).

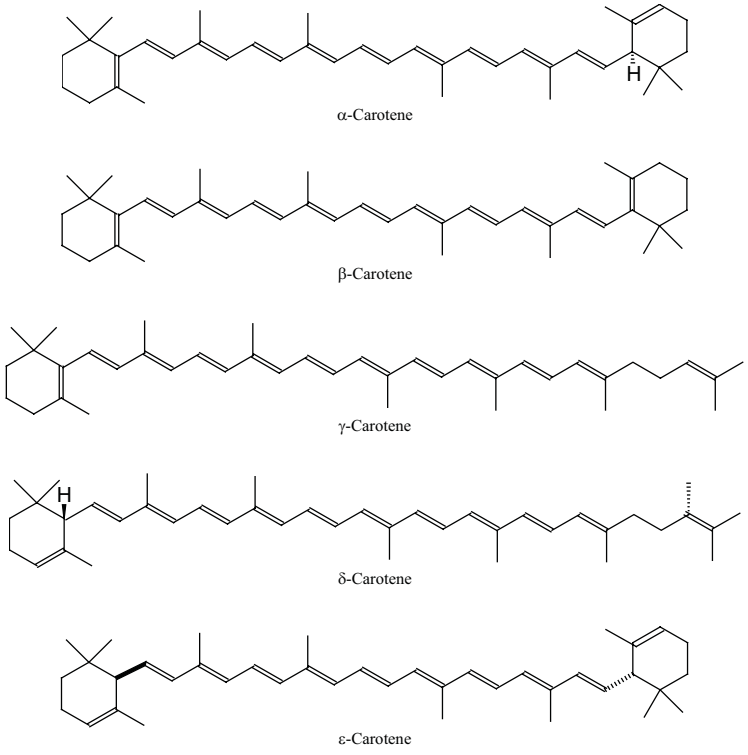

Figure 1. Chemical structure of carotene series.

Table 1. Summary of distribution of natural carotene series.

Species	Family	Group	Carotene series					Reference
			α-C	β-C	γ-C	δ-C	ε-C	
Acanthopanax sp	Araliaceae	D		√				Zorikov & Burii, 1974
Acanthophora spicifera	Rhodomelaceae	D		√				Aihara & Yamamoto, 1968
Acidum aculeatum	Aspleniaceae	FE	√	√				Czeczuga, 1985b
Acidum angulare	Aspleniaceae	FE	√	√				Czeczuga, 1985b
Adiantum capillus-veneris	Pteridaceae	FE	√	√				Czeczuga, 1985b
Adiantum pedatum	Pteridaceae	FE	√					Czeczuga, 1985b
Adiantum venustum	Pteridaceae	FE	√	√				Czeczuga, 1985b
Aesculus hippocastanum	Hippocastanaceae	D	√					Souleles & Vayas, 1986
Agastache foeniculum	Lamiaceae	D		√				Menghini et al.,1992
Aglais urticae	Nymphalidae	I		√				Kayser, 1975
Alectoria nigricans	Parmeliaceae	L	√	√				Czeczuga & Olech, 1990
Allium cepa	Liliaceae	M		√				Granado, 1992
Aloe vera	Liliaceae	M		√				Rowe & Parks, 1941
Amaranthus tricolor	Amaranthaceae	D		√				Rao, 1967
Amblystegium riparium	Amblystegiaceae	FE	√	√				Czeczuga, 1980a
Anabaena hallensis	Nostocaceae	A		√				Hai et al., 1996
Anacystis nidulans	Chroococcaceae	A		√				Buchecker et al., 1976
Ananas comosus	Bromeliaceae	M	√	√				Morgan,1966
Aneura pinguis	Aneuraceae	FE		√				Benesova, 1969
Angelica tatianae	Apiaceae	D		√				Aprikyan, 1979
Anisomorpha buprestoides	Bacunculidae	I		√				Davidson, 1991
Ankistrodesmus braunii	Oocystaceae	A		√				Burczyk, 1987
Anthurus archeri	Clathraceae	FU					√	Czygan, 1975
Aphanizomenon flos-aquae	Nostocaceae	A		√				Hertzberg & Jensen, 1966
Apium graveolens	Apiaceae	D		√				Fraczek et al., 1977 Gupta et al., 1980
Aplysia fasciata	Aplysiidae	S		√				Czeczuga, 1984
Aplysia rosea	Aplysiidae	S	√	√				Czeczuga, 1984
Arabidopsis thaliana	Brassicaceae	D		√				Parry & Horgan, 1992
Argania spinosa	Sapotaceae	D		√				Collier &Lemaire, 1974
Arnica montana	Asteraceae	D	√	√				Vanhaelen, 1973
Aronia melanocarpa	Rosaceae	D		√				Razungles et al., 1989
Artemisia dracunculus	Asteraceae	D		√				Prodan et al., 1973 Trofimova, 1977
Artemisia sylvatica	Asteraceae	D		√				Moon et al., 1999
Arum maculatum	Araceae	M		√				Valadon & Mummery, 1975
Ascidia zara	Ascidiidae	S		√				Ookubo & Matsuno, 1985
Ascophyllum nodosum	Fucaceae	A		√				Haugan & Jensen, 1994
Asparagus officinalis	Liliaceae	M	√	√				Simpson et al., 1977 Bureau & Bushway, 1986 Granado et al., 1992
Aspidium lobatum	Dryopteridaceae	FE	√	√				Czeczuga, 1985b
Asplenium lanceolatum	Aspleniaceae	FE	√	√				Czeczuga, 1985b
Asplenium trichomanes	Aspleniaceae	FE	√					Czeczuga, 1985b
Asterias amurensis	Asteriidae	S		√				Maoka et al., 1989
Asterina pectinifera	Asterinidae	S		√				Maoka et al., 1989
Athyrium filix- femina	Dryopteridaceae	FE		√				Czeczuga, 1985b
Averrhoa carambola	Oxalidaceae	D		√			√	Gross, 1983
Basella alba	Basellaceae	D		√				Cyunel & Czygan, 1989
Berberis amurensis	Berberidaceae	D		√				Shapiro, 1983
Berberis integerrima	Berberidaceae	D		√				Shapiro, 1983
Berberis koreana	Berberidaceae	D		√				Shapiro, 1983
Berberis sieboldii	Berberidaceae	D		√				Shapiro, 1983
Berberis thunbergii	Berberidaceae	D		√				Shapiro, 1983
Berberis vulgaris	Berberidaceae	D		√				Shapiro, 1983
Beta vulgaris	Chenopodiaceae	D	√	√				Granado et al., 1992 Bureau & Bushway, 1986
Bixa orellana	Bixaceae	D		√				Angelucci et al., 1980 Tirimanna, 1981
Blakeslea trispora	Choanephoraceae	FU		√	√			Feofilova & Red'kina, 1975 Feofilova, 1974
Blechnun occidentale	Blechnaceae	FU	√	√				Czeczuga, 1985b
Boehmeria nivea	Urticaceae	D	√	√				Santos, 1980
Botrylloides violaceus	Styelidae	S		√				Ookubo & Matsuno, 1985 Matsuno & Sakaguchi, 1984
Botryllus schlosseri	Styelidae	S		√				Ookubo & Matsuno, 1985
Brassica chinensis	Brassicaceae	D		√				Ortaliza, 1969

Species	Family	Group	Carotene series					Reference
			α-C	β-C	γ-C	δ-C	ε-C	
Brassica napus	Brassicaceae	D		√			√	Joyce, 1954
Brassica oleracea	Brassicaceae	D	√	√				Granado et al., 1992 Bureau & Bushway, 1986 Pospisilova, 1959 Takagi, 1985 Khachik et al., 1999 Wu et al., 1992 Bauer & Demirovska, 1982
Bromelia fastuosa	Bromeliaceae	M	√	√				Bobbio & Scamparini, 1980
Bryocaulon divergens	Stereocaulaceae	L	√	√				Czeczuga & Olech, 1990
Bufo calamita	Bufonidae	FR	√	√				Czeczuga, 1983
Caesalpinia japonica	Fabaceae	D		√				Imamura et al., 1980
Calendula arvensis	Asteraceae	D	√	√	√	√		Baraud, 1958
Calendula officinalis	Asteraceae	D	√	√	√		√	Gusakova, 1983 Zechmeister et al., 1932a Zechmeister et al., 1932b Banaszkiewicz et al., 1963 Goodwin, 1954 Toth & Szabolics,1981 Movchan, 1960 Baszynski, 1954
Camellia sasanqua	Theaceae	D	√					Fishman & Chikovani, 1990a
Cantharellus cibarius	Cantharellaceae	FU	√	√	√			Jui et al., 1998
Cantharellus lateritus	Cantharellaceae	FU	√	√				Jui et al., 1998
Cantharellus tabernensis	Cantharellaceae	FU	√	√	√			Jui et al., 1998
Capparis decidua	Capparidaceae	D		√				Gaind et al., 1970
Capparis zeylanica	Capparidaceae	D		√				Laddha & Jolly, 1985
Capsicum annuum	Solanaceae	D	√	√			√	Bureau & Bushway, 1986 Deli et al., 1996 Czinkotai et al., 1989 Biacs et al., 1993 Rodrigues et al.,1988 Mosquera et al., 1992 Mosquera et al., 1994 Mosquera et al., 1993 Gregory et al., 1987
Carcinus maenas	Portunidae	S			√	√		Czeczuga, 1975
Carica papaya	Caricaceae	D		√	√		√	Rao, 1967 Subbarayan & Cama, 1964 Topuriya, 1990 Giri et al., 1980 Yamamoto, 1964 Strocchi et al., 1977
Carthamus tinctorius	Asteraceae	D		√				Baszynski, 1954
Catha edulis	Celastraceae	D		√				Getahun et al., 1973
Cephalotaxus sp	Cephalotaxaceae	G		√	√			Yadav et al., 1987
Cerambyx cerdo	Cerambycidae	I	√	√				Czeczuga, 1988
Ceratodon purpureus	Ditrichaceae	FE		√				Czeczuga, 1980a
Ceterach officinarum	Aspleniaceae	FE	√	√				Czeczuga, 1985b
Cetraria andrejevii	Parmeliaceae	L	√	√				Czeczuga & Alstrup, 1987
Cetraria cucullata	Parmeliaceae	L	√	√				Czeczuga & Olech, 1990
Cetraria delisei	Parmeliaceae	L	√	√				Czeczuga & Olech, 1990 Czeczuga & Alstrup, 1987
Cetraria islandica	Parmeliaceae	L		√				Czeczuga & Alstrup, 1987
Cetraria nivalis	Parmeliaceae	L	√	√				Czeczuga & Olech, 1990 Czeczuga & Alstrup, 1987
Chattonella japonica	Vacuolariaceae	A		√				Fiksdahl et al., 1984a
Chlamydomonas reinhardti	Chlamydomonadaceae	A		√				Kitayama & Takakura, 1991 Francis et al., 1975
Chlorella fusca	Chlorellaceae	A		√				Burczyk, 1987
Chlorella saccharophila	Chlorellaceae	A		√				Burczyk, 1987
Chlorella sp	Chlorellaceae	A		√				Burczyk, 1987
Chlorella vulgaris	Chlorellaceae	A		√				Burczyk, 1987
Chlorobium tepidum	Chlorobiaceae	B			√			Takaichi et al., 1997
Chloroflexus aurantiacus	Chloroflexaceae	B		√	√			Takaichi et al., 1995
Chrysomyxa abietis	Uredinalis	FU			√			Pfeifhofer & Grill, 1984
Ciona intestinalis	Cionidae	S		√				Ookubo & Matsuno, 1985

Species	Family	Group	Carotene series					Reference
			α-C	β-C	γ-C	δ-C	ε-C	
Citrus aurantium	Rutaceae	D		√				Toth & Szabolics, 1981
Citrus limon	Rutaceae	D	√	√				Kutateladze, 1974
Citrus paradisi	Rutaceae	D	√	√	√		√	Bureau & Bushway, 1986 Heinonen et al., 1989 Rouseff et al., 1992
Citrus sinensis	Rutaceae	D	√	√				Bureau & Bushway, 1986 Malachi et al., 1974 Shim et al., 1994 Kudritskaya et al., 1983
Cladonia amaurocraea	Cladoniaceae	L	√	√				Czeczuga & Olech, 1990
Cladonia cenotea	Cladoniaceae	L		√				Czeczuga, 1985a
Cladonia coccifera	Cladoniaceae	L	√	√				Czeczuga & Olech, 1990 Czeczuga, 1985a
Cladonia cornuta	Cladoniaceae	L	√	√				Czeczuga, 1985a
Cladonia crispata	Cladoniaceae	L		√				Czeczuga, 1985a
Cladonia deformis	Cladoniaceae	L		√				Czeczuga, 1985a
Cladonia degenerans	Cladoniaceae	L	√	√				Czeczuga, 1985a
Cladonia foliacea	Cladoniaceae	L		√				Czeczuga et al., 1988
Cladonia furcata	Cladoniaceae	L		√				Czeczuga, 1985a
Cladonia glauca	Cladoniaceae	L		√				Czeczuga, 1985a
Cladonia gracilis	Cladoniaceae	L		√				Czeczuga, 1985a
Cladonia impexa	Cladoniaceae	L	√	√				Czeczuga, 1985a
Cladonia macilenta	Cladoniaceae	L	√					Czeczuga, 1985a
Cladonia mitis	Cladoniaceae	L		√				Czeczuga & Alstrup, 1987
Cladonia nylanderi	Cladoniaceae	L		√				Czeczuga et al., 1988
Cladonia ochrochlora	Cladoniaceae	L		√				Czeczuga, 1985a
Cladonia rangiferina	Cladoniaceae	L		√				Czeczuga, 1985a
Cladonia scabriuscula	Cladoniaceae	L		√				Czeczuga, 1985a
Cladonia sylvatica	Cladoniaceae	L		√				Czeczuga, 1985a
Cladonia turgida	Cladoniaceae	L		√				Czeczuga, 1985a
Cladonia verticillata	Cladoniaceae	L		√				Czeczuga, 1985a
Cochlospermum vitifoleum	Cochlospermaceae	D		√	√			Dixit & Srivastava, 1992a
Colocasia esculenta	Araceae	M		√				Rao, 1967
Coniogramme japonica	Pteridaceae	FE	√					Czeczuga, 1985b
Corallina elongata	Corallinaceae	A		√				Palermo et al., 1991
Corallina officinalis	Corallinaceae	A		√				Palermo et al., 1991
Cornicularia divergens	Parmeliaceae	L		√				Czeczuga & Alstrup, 1987
Crambe abyssinica	Brassicaceae	D		√				Baszynski, 1954
Crepis tectorum	Asteraceae	D	√		√			Sergeeva et al., 1984
Crocus sativus	Iridaceae	M		√	√			Duquenois, 1972 Kuhn & Winterstein, 1933 Pfander et al., 1982
Ctenopharyngodon idella	Cyprinidae	S		√				Czeczuga, 1981
Cucumis melo	Cucurbitaceae	D	√	√			√	Bureau & Bushway, 1986 Rojas & Diaz, 1977
Cucumis sativus	Cucurbitaceae	D		√				Granado et al., 1992
Cucurbita maxima	Cucurbitaceae	D		√				Neamtu et al., 1990
Cucurbita moschata	Cucurbitaceae	D		√				Doiiode & Sulledmath, 1986
Cucurbita pepo	Cucurbitaceae	D		√				Granado et al., 1992 Neamtu et al., 1990
Cucurbita sp	Cucurbitaceae	D	√	√				Bureau & Bushway, 1986
Cuscuta australis	Convolvulaceae	D		√	√			Baccarini et al., 1965
Cyclopterus lumpus	Cyclopteridae	S		√				Czeczuga, 1982
Cynara scolymus	Asteraceae	D		√				Granado et al., 1992
Cyrtomium falcatum	Dryopteridaceae	FE	√	√				Czeczuga, 1985b
Cystoclonium purpureum	Rhodophyllidaceae	A	√					Findlay & Patil, 1986
Cystopteris bulbifera	Dryopteridaceae	FE		√				Czeczuga, 1985b
Cystopteris fragilis	Dryopteridaceae	FE		√				Czeczuga, 1985b
Dactylis glomerata	Poaceae	M		√				Pollard, 1936
Daucus carota	Apiaceae	D	√	√	√		√	Granado et al., 1992 Rao, 1967 Bureau & Bushway, 1986 Coxon et al., 1973 Rhodes & Hall, 1975 Chandra & Nair, 1997 Barth et al., 1995 Vega et al., 1996

Species	Family	Group	Carotene series					Reference
			α-C	β-C	γ-C	δ-C	ε-C	
								Van Breemen, 1996 Sun, 1994 Sato, 1992 Mok et al., 1976 Czygan & Herboth, 1976 Toth et al., 1995 Koch et al, 1991 Buishand & Gabelman, 1978 Baruffaldi et al., 1981 Sarma & Sarma, 1978 Nishi et al., 1974
Davallia solida	Davalliaceae	FE	√					Czeczuga, 1985b
Dermatocarpon miniatum	Verrucariaceae	L		√				Czeczuga & Alstrup, 1987
Desmarestia aculeata	Desmarestiaceae	A		√				Findlay & Patil, 1985
Didemnum moselyi	Didemnidae	S		√				Ookubo & Matsuno, 1985
Dioscorea cayenensis	Dioscoreaceae	M		√				Martin & Ruberte, 1975
Dioscorea versicolor	Dioscoreaceae	M		√			√	Rao, 1967
Diospyros kaki	Ebenaceae	D	√	√	√		√	Fishman & Chikovani, 1990b Kudritskaya et al., 1984 Ebert & Gross, 1985
Diplazium sibiricum	Dryopteridaceae	FE	√	√				Czeczuga, 1985b
Drepanocladus fluitans	Amblystegiaceae	FE		√				Boston et al., 1991
Dryopteris carthusiana	Dryopteridaceae	FE	√	√				Czeczuga, 1985b
Dryopteris dilatata	Dryopteridaceae	FE		√				Czeczuga, 1985b
Dryopteris filix-mas	Dryopteridaceae	FE		√				Czeczuga, 1985b
Dryopteris parasitica	Dryopteridaceae	FE	√					Czeczuga, 1985b
Dunaliella bardawil	Dunaliellaceae	A	√	√				Ben-Amotz et al., 1990 Takenaka et al., 1993 Mokady et al., 1989
Dunaliella salina	Dunaliellaceae	A	√	√				Ben-Amotz et al., 1990 Chen et al., 1995
Elaeis guineensis	Arecaceae	M	√	√	√			Mariath et al., 1989 Argoud, 1958 Manorama & Rukmini, 1992
Eleutherococcus koreanus	Araliaceae	D		√				Bladt et al., 1990
Eleutherococcus senticosus	Araliaceae	D		√				Zorikov & Burii, 1974
Equisetum arvensi	Equisetaceae	FE	√	√				Czeczuga, 1985b
Equisetum fluviatile	Equisetaceae	FE	√	√	√			Czeczuga, 1985b
Equisetum hyemale	Equisetaceae	FE	√	√				Czeczuga, 1985b
Equisetum palustre	Equisetaceae	FE		√				Czeczuga, 1985b
Equisetum pratense	Equisetaceae	FE		√				Czeczuga, 1985b
Equisetum sylvaticum	Equisetaceae	FE	√	√				Czeczuga, 1985b
Equisetum telmateia	Equisetaceae	FE	√	√				Czeczuga, 1985b
Eriobotrya japonica	Rosaceae	D	√					Ben-Amotz et al., 1990
Erysimum diffusum	Brassicaceae	D	√					Gusakova, 1983
Erythrotrichia carnea	Erythropeltidaceae	A		√				Bjoernland, 1984
Euglena gracilis	Euglenaceae	A		√			√	Gross et al., 1975
Euglena sanguinea	Euglenaceae	A		√				Grung & Jensen, 1993
Fibrocapsa japonica	To be determined	A		√				Fiksdahl et al., 1984a
Ficus carica	Moraceae	D		√				Karag'ozova, 1974
Fontinalis antipyretica	Fontinalaceae	FE	√	√				Czeczuga, 1980a Boston et al., 1991
Fontinalis squamosa	Fontinalaceae	FE	√	√				Czeczuga, 1980a
Fragaria ananassa	Rosaceae	D		√				Gross, 1972
Fragaria sp	Rosaceae	D	√	√				Bureau & Bushway, 1986
Fucus serratus	Fucaceae	A		√				Haugan & Jensen, 1954
Fucus vesiculosus	Fucaceae	A		√				Haugan & Jensen, 1954 Liaaen & Sorensen, 1955 Halsall & Hills, 1971
Funaria hygrometrica	Funariaceae	FE		√	√			Czeczuga, 1980a
Fusinus perplexus	Fasciolariidae	S		√				Matsuno & Tsushima, 1989
Galium helderichii	Rubiaceae	D		√				Tzakou et al., 1988
Galium mollugo	Rubiaceae	D		√				Shapiro et al., 1985
Galium tinctorium	Rubiaceae	D		√				Shapiro et al., 1985
Genista dentata	Fabaceae	D	√	√				Schon & Mesqita, 1936
Ginkgo biloba	Ginkgoaceae	G	√	√	√			Yadav et al., 1987 Matile et al., 1992

Species	Family	Group	Carotene series					Reference
			α-C	β-C	γ-C	δ-C	ε-C	
Glycine max	Fabaceae	D		√				Rao, 1967 Baszynski, 1954
Gnetum africanum	Gnetaceae	G		√				Njoku et al., 1997
Gomphosphaeria aponina	Chroococaceae	A		√				Eng-Wilmont & Martin, 1979
Gonyostomum semen	Vacuolariaceae	A		√				Fiksdahl et al., 1984a
Gossypium barbadense	Malvaceae	D		√				Khodzhaev, 1981
Gossypium hirsutum	Malvaceae	D	√	√				Jones, 1979 Hanny & Hedin, 1972
Gossypium sp	Malvaceae	D	√	√				Mc Cormick, 1982
Gracilaria lichenoides	Gracilariaceae	A		√				Aihara & Yamamoto, 1968
Grammatophora oceanica	Bacillariophyceae	A		√				Pennington et al., 1988
Grimmia pulvinata	Grimmiaceae	FE		√				Czeczuga, 1980a
Gymnodinium catenatum	Gymnodiniaceae	A		√				Hallegraeff et al., 1991
Gymnogramma sulphurea	Pteridaceae	FE	√	√				Czeczuga, 1985b
Gyrodinium aureolum	Gymnodiniaceae	S		√				Tangen & Bjoernland, 1981
Gyrodinium sp	Gymnodiniaceae	S		√				Bjoerland & Tangen, 1979
Haematococcus lacustris	Haematococcaceae	S		√				Donkin, 1976
Halobacterium cutirubrum	Halobacteriaceae	B		√				Kushwaha et al., 1975
Halocynthia roretzi	Pyuridae	S		√				Ookubo & Matsuno, 1985 Matsuno et al., 1984b
Hedysarum polybotrys	Fabaceae	D		√				Jiang, 1989
Helianthemum numularum	Cistaceae	D	√	√				Marius et al., 1994
Helianthus annuus	Asteraceae	D		√				Baszynski, 1954
Heliopsis scabra	Asteraceae	D		√				Raszeja & Muszynska, 1980
Heterosigma akashiwo	Dinophyceae	A		√				Fiksdahl et al., 1984b
Hexabranchus sp	Hexabranchidae	S		√				Tanaka et al., 1992
Hibiscus esculentus	Malvaceae	D	√	√				Bureau & Bushway, 1986
Hibiscus sabdariffa	Malvaceae	D		√				Rao, 1967
Hibiscus syriacus	Malvaceae	D	√	√				Hanny & Hedin, 1972 Hanny et al., 1972 Chernenko & Umarov, 1974
Hippophae rhamnoides	Elaeagnaceae	D	√	√	√			Zorikov & Burii, 1974 Sergeeva et al., 1979 Gachechiladze et al., 1981 Lagazidze et al., 1984 Zhmyrko et al., 1978
Hydrilla verticillata	Hydrocharitaceae	M		√				Lin et al., 1979
Hylocomium splendens	Hylocomiaceae	FE		√				Czeczuga, 1980a
Hypericum perforatum	Clusiaceae	D	√	√				Omarova et al., 1997 Chaplinskaya, 1956
Hypnum cupressiforme	Hypnaceae	FE		√	√			Czeczuga, 1980a
Ianthella basta	Ianthellidae	S		√				Ramdahl et al., 1981
Ianthella flabelliformis	Ianthellidae	S		√				Hertzberg et al., 1989
Ipomoea aquatica	Convolvulaceae	D		√				Ortaliza et al., 1969 Kasemsri et al., 1952
Ipomoea batatas	Convolvulaceae	D	√	√				Bureau & Bushway, 1986 Ortaliza et al., 1969
Iris germanica	Iridaceae	M		√				Buchecker & Jensen, 1975
Iris pseudacorus	Iridaceae	M		√				O'Connor & Drumm, 1941
Jania sp	Corallinaceae	A		√				Palermo et al., 1991
Lactuca sativa	Asteraceae	D	√	√				Granado et al., 1992 Bureau & Bushway, 1986
Laminaria digitata	Laminariaceae	A		√				Haugan & Jensen, 1994
Laminaria saccharina	Laminariaceae	A		√				Haugan & Jensen, 1994
Leptura rubra	Cerambycidae	I		√				Czeczuga, 1988
Lespedeza sp	Fabaceae	D		√				Zorikov & Burii, 1974
Leucobryum glaucum	Leucobryaceae	FE	√	√				Czeczuga, 1980a
Ligia exotica	Ligiidae	S		√				Matsuno et al., 1990
Lilium tenuifolium	Liliaceae	M		√				Partali et al., 1987
Lobaria linita	Lobariaceae	L	√	√				Czeczuga & Olech, 1990
Lolium perenne	Poaceae	M		√				Tamas & Popescu, 1985
Lonicera altaica	Caprifoliaceae	D		√				Shapiro et al., 1981
Lonicera caerulea	Caprifoliaceae	D		√				Shapiro et al., 1981
Lonicera edulis	Caprifoliaceae	D		√				Shapiro et al., 1981
Lonicera japonica	Caprifoliaceae	D		√	√		√	Goodwin, 1952
Lota lota	Gadidae	S		√				Czeczuga, 1978
Lotus corniculatus	Fabaceae	D		√				Ceruti et al., 1972

Species	Family	Group	Carotene series					Reference
			α-C	β-C	γ-C	δ-C	ε-C	
Lupinus albus	Fabaceae	D		√				El-Fifrawi & Hudson, 1979
Lupinus angustifolius	Fabaceae	D		√				El-Fifrawi & Hudson, 1979
Lupinus luteus	Fabaceae	D		√				El-Fifrawi & Hudson, 1979
Lupinus mutabilis	Fabaceae	D		√				El-Fifrawi & Hudson, 1979
Lycopersicon cheesmanii	Solanaceae	D		√				Chalukova et al., 1985
Lycopersicon esculentum	Solanaceae	D		√	√			Granado et al., 1992 Parry & Horgan, 1992 Laval-Martin et al., 1975
Lycopodium annotinum	Lycopodiaceae	FE		√				Czeczuga, 1985b
Lycopodium clavatum	Lycopodiaceae	FE		√				Czeczuga, 1985b
Lycopodium complanatum	Lycopodiaceae	FE		√				Czeczuga, 1985
Lycopodium selago	Lycopodiaceae	FE		√				Czeczuga, 1985b
Malpighia punicifolia	Malpighiaceae	D		√	√		√	Baraud, 1958
Mangifera indica	Anacardiaceae	D	√	√	√			Meimban et al., 1983 Mercadante et al., 1988b
Mantoniella squamata	Nephroselmidaceae	A		√				Egeland et al., 1995
Marchantia polymorpha	Marchantiaceae	FE	√	√	√			Czeczuga, 1980a
Matteuccia struthiopteris	Dryopteridaceae	FE	√	√				Czeczuga, 1985b Bushway et al., 1985
Mauritia vinifera	Arecaceae	M		√				Mariath et al., 1989
Medicago arborea	Fabaceae	D		√				Ignasiak & Lesins, 1975
Medicago cancellata	Fabaceae	D		√				Ignasiak & Lesins, 1975
Medicago carstiensis	Fabaceae	D	√	√				Ignasiak & Lesins, 1975
Medicago cretacea	Fabaceae	D		√				Ignasiak & Lesins, 1975
Medicago daghestanica	Fabaceae	D	√	√				Ignasiak & Lesins, 1975
Medicago falcata	Fabaceae	D		√				Ignasiak & Lesins, 1975
Medicago glomerata	Fabaceae	D		√				Ignasiak & Lesins, 1975
Medicago glutinosa	Fabaceae	D		√				Ignasiak & Lesins, 1975
Medicago hemicycla	Fabaceae	D	√	√				Ignasiak & Lesins, 1975
Medicago hybrida	Fabaceae	D	√	√				Ignasiak & Lesins, 1975
Medicago leiocarpa	Fabaceae	D	√	√				Ignasiak & Lesins, 1975
Medicago marina	Fabaceae	D	√	√				Ignasiak & Lesins, 1975
Medicago papillosa	Fabaceae	D		√				Ignasiak & Lesins, 1975
Medicago pironae	Fabaceae	D	√	√				Ignasiak & Lesins, 1975
Medicago platycarpos	Fabaceae	D	√	√				Ignasiak & Lesins, 1975
Medicago prostrata	Fabaceae	D		√				Ignasiak & Lesins, 1975
Medicago rhodopea	Fabaceae	D	√	√				Ignasiak & Lesins, 1975
Medicago rupestris	Fabaceae	D		√				Ignasiak & Lesins, 1975
Medicago ruthenica	Fabaceae	D	√	√				Ignasiak & Lesins, 1975
Medicago sativa	Fabaceae	D		√				Toth et al., 1995 Ignasiak & Lesins, 1975
Medicago saxatilis	Fabaceae	D	√	√				Ignasiak & Lesins, 1975
Medicago suffruticosa	Fabaceae	D	√	√				Ignasiak & Lesins, 1975
Melinis minutiflora	Poaceae	M		√				Calle Alvarez et al., 1986
Metasequoia glyptosboides	Taxodiaceae	G	√	√	√			Czeczuga, 1987
Microlepia speluncae	Dennstaedtiaceae	FE	√	√				Czeczuga, 1985b
Millingtonia hortensis	Bignoniaceae	D		√				Mangayarkarasi et al.,1984
Mimosa biuncifera	Fabaceae	D		√				Kudritskaya et al., 1988a
Mimulus cupreus	Scrophulariaceae	D		√				Goodwin & Thomas, 1964
Mimulus tigrinus	Scrophulariaceae	D		√				Goodwin & Thomas, 1964
Mnium affine	Mniaceae	FE	√	√				Czeczuga, 1980a
Mnium cuspidatum	Mniaceae	FE	√	√				Czeczuga, 1980a
Mnium undulatum	Mniaceae	FE	√	√				Czeczuga, 1980a
Momordica charantia	Cucurbitaceae	D		√	√	√		Rodriguez et al., 1976
Monarda didyma	Lamiaceae	D		√				Brieskorn & Meister, 1965
Monochamus pistor	Cerambycidae	I		√				Czeczuga, 1988
Montanoa karwinski	Asteraceae	D		√				Quijano et al., 1995
Morinda citrifolia	Rubiaceae	D		√				Aalbersberg et al., 1993
Moringa pterygosperma	Moringaceae	D		√				Ortaliza et al., 1969
Morus alba	Moraceae	D		√				Yen et al., 1996
Murraya euchrestifolia	Rutaceae	D		√				Wu, 1991
Mycobacterium brevicale	Mycobacteriaceae	A	√	√				Daraseliya et al., 1979
Mycobacterium kansasii	Mycobacteriaceae	A		√				David, 1974
Navicula delognei	Naviculaceae	A		√				Findlay & Patil, 1984
Navicula pelliculosa	Naviculaceae	A		√				Pennington et al., 1988
Nephrolepis exaltata	Nephrolepidaceae	FE		√				Czeczuga, 1985b
Nephroma arcticum	Peltigeraceae	L		√				Czeczuga & Olech, 1990.

Species	Family	Group	Carotene series					Reference
			α-C	β-C	γ-C	δ-C	ε-C	
Nephroma laevigatum	Peltigeraceae	L		√				Czeczuga et al., 1988
Nephroma parile	Peltigeraceae	L		√				Czeczuga & Alstrup, 1987
Nicotiana plumbaginifolia	Solanaceae	D		√				Parry & Horgan, 1992
Nicotiana tabacum	Solanaceae	D		√				Lichtenthaler et al., 1975
Nitzschia sp	Nitzschiaceae	A		√				Pennington et al., 1988
Ocimum sanctum	Lamiaceae	D		√				Skaltsa et al., 1987
Odontoschisma denudatum	Odontoschismaceae	FE	√	√				Czeczuga, 1980a
Olea europaea	Oleaceae	D	√	√	√			Golubev et al., 1986
Onoclea sensibilis	Dryopteridaceae	FE		√				Czeczuga,1985b
Orthosiphon grandiflorus	Lamiaceae	D	√	√				Kudritskaya et al., 1988b
Orychophragmus violaceus	Brassicaceae	D		√				Li et al., 1997
Oscillatoria agardhii	Oscillatoriaceae	A		√				Ronneberg et al., 1980 Foss et al., 1986
Oscillatoria bornetii	Oscillatoriaceae	A		√				Foss et al., 1986
Oscillatoria limosa	Oscillatoriaceae	A		√				Foss et al., 1986 Francis et al., 1970
Oscillatoria rubescens	Oscillatoriaceae	A		√				Ronneberg et al., 1980
Paralithodes brevipes	Lithodidae	S		√				Matsuno Maoka, 1988
Parmelia acetabulum	Parmeliaceae	L		√				Czeczuga et al., 1989
Passiflora edulis	Passifloraceae	D		√			√	Mercadante et al., 1998a
Pellaea rotundifolia	Pteridaceae	FE		√				Czeczuga, 1985b
Pellia endiviaefolia	Pelliaceae	FE		√				Asakawa & Takemoto, 1978
Pellia fabbroniana	Pelliaceae	FE		√				Czeczuga, 1980a
Peltigera aphthosa	Peltigeraceae	L	√	√				Czeczuga, 1986 Czeczuga, 1980b
Peltigera canina	Peltigeraceae	L		√				Czeczuga, 1980b
Peltigera erumphens	Peltigeraceae	L		√				Czeczuga, 1980b
Peltigera hazszlynskyi	Peltigeraceae	L		√			√	Czeczuga, 1980b
Peltigera leucophlebia	Peltigeraceae	L		√				Czeczuga & Olech, 1990 Czeczuga, 1980b
Peltigera malacea	Peltigeraceae	L	√	√				Czeczuga & Olech, 1990 Czeczuga, 1980b
Peltigera polydactyla	Peltigeraceae	L		√				Czeczuga, 1980b
Peltigera ponojensis	Peltigeraceae	L		√				Czeczuga et al., 1989
Peltigera praetexta	Peltigeraceae	L	√	√			√	Czeczuga, 1980b
Peltigera rufescens	Peltigeraceae	L		√				Czeczuga & Alstrup, 1987 Czeczuga, 1980b
Pelvetia canaliculata	Fucaceae	A		√				Haugan & Jensen, 1954
Penaeus japonicus	Penaeidae	S		√				Katagiri et al., 1987
Persea americana	Lauraceae	D	√	√			√	Gross et al., 1972
Petroselinum crispum	Apiaceae	D		√				Francis & Isaken, 1989
Phaeocystis sp	Chrysocapsaceae	S		√				Bjornland et al., 1988
Phaffia rhodozyma	Hyphomycetes	FU		√				Yajima et al., 1993
Phaseolus vulgaris	Fabaceae	D	√	√				Granado et al., 1992 Rao, 1967 Parry & Horgan, 1992 Bureau & Bushway, 1986 Wu et al., 1992 Lopez-Hernandez et al., 1993
Phegopteris dryopteris	Thelypteridaceae	FE		√				Czeczuga, 1985b
Pheodactylum tricornutum	To be determined	A		√				Pennington et al., 1988
Phormidium laminosum	Oscillatoriaceae	A		√				Fresnedo et al., 1991
Phycomyces blakesleeanus	Mucoraceae	FU		√	√			Bramley & Davies, 1975 Bramley & Davies, 1976 Elahi et al., 1975 Eslava et al., 1974 Desai et al., 1975 Lee et al., 1975
Physalis alkekengi	Solanaceae	D		√			√	Baraud, 1958
Physconia pulverulacea	Physciaceae	L	√	√				Czeczuga, 1986
Picea abies	Pinaceae	G	√	√	√			Pfeifhofer & Grill, 1984 Grill et al., 1984 Hoque, 1988
Pinus massoniana	Pinaceae	G		√				Zhou et al., 1984
Pinus roxburghii	Pinaceae	G		√				Yadav et al., 1987
Piper betle	Piperaceae	D		√				Azuine et al., 1991

Species	Family	Group	Carotene series					Reference
			α-C	β-C	γ-C	δ-C	ε-C	
Pisum sativum	Fabaceae	D	√	√				Parry & Horgan, 1992 Bureau & Bushway, 1986
Pleurozia schreberi	Pleuroziaceae	FE		√				Czeczuga, 1980a
Plumbago zeylanica	Plumbaginaceae	D		√				Heble, 1977
Polycitor proliferus	Polycitoridae	S		√				Ookubo & Matsuno, 1985
Polystichum tsus- sinense	Dryopteridaceae	FE		√				Czeczuga, 1985b
Polytrichum commune	Polytrichaceae	FE	√	√				Czeczuga, 1980a
Polytrichum formosum	Polytrichaceae	FE	√	√				Czeczuga, 1980a
Polytrichum gracile	Polytrichaceae	FE		√				Czeczuga, 1980a
Polytrichum juniperinum	Polytrichaceae	FE		√				Czeczuga, 1980a
Polytrichum piliferum	Polytrichaceae	FE		√	√			Czeczuga, 1980a
Porphyra tenera	Bangiaceae	A		√				Okai et al., 1996
Portulaca oleracea	Portulacaceae	D		√				Simopoulos et al., 1992
Potentilla argentea	Rosaceae	D	√	√				Goncharov & Kotov, 1992
Potentilla erecta	Rosaceae	D	√	√				Goncharov & Kotov, 1992
Protula tubularia	Serpulidae	S	√	√				Czeczuga, 1984
Prunus armeniaca	Rosaceae	D	√	√				Bureau & Bushway, 1986
Prunus avium	Rosaceae	D		√				Gross, 1985
Prunus domestica	Rosaceae	D		√				Heinonen et al., 1989
Prunus padus	Rosaceae	D		√				Zorikov & Burii, 1974
Prunus persica	Rosaceae	D	√	√				Bureau & Bushway, 1986 Mc Carty & Lesley, 1954 Molnar et al., 1987
Pseudoscourfieldia marina	Prasinophyceae	A		√				Egeland et al., 1995
Pteridium aquilinum	Dennstaedtiaceae	FE	√	√				Czeczuga, 1985b
Ptilium crista-castrensis	Hypneaceae	FE	√	√				Czeczuga, 1980a
Pulicaria paludosa	Asteraceae	D		√				Diaz et al., 1988
Pyracantha sp	Rosaceae	D		√				Wang et al., 1992
Pyramimonas parkeae	Pyramimonadaceae	A		√				Sasa et al., 1992
Ramalina capitata	Ramalinaceae	L		√				Hoyos & Manrique, 1995
Ranunculus ficaria	Ranunculaceae	D	√					Cameroni & Bernabei, 1957
Raphanus sativus	Brassicaceae	D		√				Becker & Lichtenthaler, 1975
Renealmia alpinia	Zingiberaceae	M		√				Lognay et al., 1991
Rhaponticum carthamoides	Asteraceae	D		√				Gusakova, 1983
Rhododendron ellipticum	Ericaceae	D		√				Ho & Lin, 1995
Rhodomicrobium vannielii	Rhodospirillaceae	B		√				Britton et al., 1995
Rhodotorula glutinis	Hyphomycetes	FU		√				Hayman et al., 1974
Rhodotorula mucilaginosa	Hyphomycetes	FU		√	√			Margalith & Meydav, 1968
Rhodotorula rubra	Hyphomycetes	FU		√				Shih & Hang, 1996
Riccardia sinuata	Aneuraceae	FE		√				Benesova et al., 1969
Riccia fluitans	Ricciaceae	FE	√	√				Czeczuga, 1980a
Ricinus communis	Euphorbiaceae	D		√				Baszynski, 1954
Rivina humilis	Phytolaccaceae	D		√				Lopez, 1982
Rosa canina	Rosaceae	D		√				Razungles et al., 1989 Hodisan et al., 1997
Rosa foetida	Rosaceae	D		√				Marki-Fische et al., 1984
Rosa pomifera	Rosaceae	D		√				Marki-Fischer et al., 1983
Rosa rugosa	Rosaceae	D		√				Razungles et al., 1989
Rosa sp	Rosaceae	D		√				Williams & Goodwin, 1965
Rubus idaeus	Rosaceae	D	√	√				Bureau & Bushway, 1986
Rumex vesicarius	Polygonaceae	D		√				Rao, 1967
Salvia arisanensis	Lamiaceae	D		√				Wu & Huang, 1975
Salvia hayatana	Lamiaceae	D		√				Wu & Huang, 1975
Salvia hualiensis	Lamiaceae	D		√				Wu & Huang, 1975
Salvia keitaoensis	Lamiaceae	D		√				Wu & Huang, 1975
Salvia scapiformis	Lamiaceae	D		√				Wu & Huang, 1975
Sandersonia aurantiaca	Liliaceae	M		√				Lewis et al., 1998
Sansevieria cylindrica	Agavaceae	M		√				Moustafa et al., 1986
Sarcopoterium spinosum	Rosaceae	D		√				Vitsaropoulou et al., 1981
Scenedesmus obliquus	Scenedesmaceae	A		√				Burczyk, 1987
Scenedesmus quadricauda	Scenedesmaceae	A		√				Burczyk, 1987
Sesbania grandiflora	Fabaceae	D	√					Andal & Sulochana, 1986
Skeletonema costatum	Coscinodiscaceae	A		√				Pennington et al., 1988
Skeletonema menzelii	Coscinodiscaceae	A		√				Pennington et al., 1988
Smilax sp	Liliaceae	M		√				Kudritskaya et al., 1982
Solanum khasianum	Solanaceae	D		√				Uddin & Chowdhury, 1982
Solanum laciniatum	Solanaceae	D		√				Munteanu et al., 1981

Species	Family	Group	Carotene series					Reference
			α-C	β-C	γ-C	δ-C	ε-C	
								Munteanu et al., 1980
Solanum nigrum	Solanaceae	D	√					Dan et al., 1982
Solanum persicum	Solanaceae	D	√	√				Novruzov, 1983
Solanum tuberosum	Solanaceae	D	√	√				Granado et al., 1992
Solorina crocea	Peltigeraceae	L		√				Czeczuga & Olech, 1990
Sorbus aucuparia	Rosaceae	D	√	√				Valadon et al., 1972
Sphaerophorus globosus	Sphaerophoraceae	L		√				Czeczuga & Olech, 1990
Sphagnum apiculatum	Sphagnaceae	FE	√	√				Czeczuga, 1980a
Sphagnum magellanicum	Sphagnaceae	FE	√	√				Czeczuga, 1980
Sphagnum palustre	Sphagnaceae	FE	√	√	√			Czeczuga, 1985b
Sphagnum recurvum	Sphagnaceae	FE	√	√	√			Czeczuga, 1985b
Sphagnum squarrosum	Sphagnaceae	FE	√	√	√			Czeczuga, 1985b
Spinacia oleracea	Chenopodiaceae	D	√	√				Granado et al., 1992 Rao, 1967 Bureau & Bushway, 1986
Spirulina dunaliella	Oscillatoriaceae	A		√				Jenkins et al., 1993
Spirulina sp	Oscillatoriaceae	A		√				Schwartz et al., 1988
Sporobolomyces chosaticus	Hyphomycetes	FU		√				Golyakov & Tikhonova, 1975
Sporobolomyces paraseus	Hyphomycetes	FU		√				Golyakov & Tikhonova, 1975
Sporobolomyces roseus	Hyphomycetes	FU		√				Golyakov & Tikhonova, 1975
Staphylococcus aureus	Micrococcaceae	B				√	√	Mel'nikova & Ignatov, 1973 Czecuga & Heczko, 1988
Stemmadenia glabra	Apocynaceae	D		√				Ciccio et al., 1982
Stereocaulon alpinum	Stereocaulaceae	L	√	√				Czeczuga & Olech, 1990 Czeczuga & Alstrup, 1987 Czeczuga, 1986
Stereocaulon paschale	Stereocaulaceae	L	√					Czeczuga & Alstrup, 1987
Stereocaulon vesuvianum	Stereocaulaceae	L	√	√				Czeczuga & Olech, 1990 Czeczuga et al., 1989
Stereocaulon vulcani	Stereocaulaceae	L		√				Czeczuga et al., 1988
Stevia rebaudiana	Asteraceae	D		√				Cheng & Chang, 1983
Stichopus regalis	Stichopodidae	S		√				Czeczuga, 1984
Sticta canariensis	Lobariaceae	L		√				Czeczuga et al., 1988
Styela clava	Styelidae	S		√				Ookubo & Matsuno, 1985
Styela plicata	Styelidae	S		√				Ookubo & Matsuno, 1985
Suberites sericeus	Suberitidae	S		√				Matsuno et al., 1984a
Symphytum officinale	Boraginaceae	D		√				Fukumoto & Kuwano, 1975
Tagetes erecta	Asteraceae	D		√				Khachik et al., 1999
Tamus communis	Dioscoreaceae	M		√	√		√	Baraud, 1958
Tanacetum vulgare	Asteraceae	D		√				Banthorpem & Justice, 1972
Taraxacum officinale	Asteraceae	D		√				Booth, 1964
Tecoma argentea	Bignoniaceae	D		√				Dixit & Srivastava, 1992b
Tethya aurantia	Clionidae	S	√	√			√	Czeczuga, 1984
Tetragonia tetragonoides	Aizoaceae	D		√				Lee, 1975
Tetraselmis sp	Chlamydomonadaceae	A		√				Egeland et al., 1995
Tetraselmis wettsteinii	Chlamydomonadaceae	A		√				Egeland et al., 1995
Thalassiosira eccentrica	Thalassiosiraceae	A		√				Pennington et al., 1988
Thalassiosira oceanica	Thalassiosiraceae	A		√				Pennington et al., 1988
Thalassiosira pseudonana	Thalassiosiraceae	A		√				Pennington et al., 1988
Thalassiosira rotula	Thalassiosiraceae	A		√				Pennington et al., 1988
Thamnolia vernicularis	Siphulaceae	L		√				Czeczuga & Olech, 1990
Thelypteris palustris	Thelypteridaceae	FE		√				Czeczuga, 1985b
Thespesia populnea	Malvaceae	D		√				Datta, 1968
Thorascophaera heimii	Coccolithophycidae	S		√				Bjornland, 1990
Trichosanthes cucumeroide	Cucurbitaceae	D		√	√			Matsuno & Nagata, 1971 Matsuno et al., 1970
Trifolium repens	Fabaceae	D	√		√			Sergeeva et al., 1984
Trigonella foenum-gracum	Fabaceae	D		√				Rao, 1967
Triticum durum	Poaceae	M		√				Lier, 1975
Ulex europaeus	Fabaceae	D	√	√				Schon, 1936
Ulex gallii	Fabaceae	D	√	√				Schon, 1936
Ulota ulophylla	Orthotrichaceae	FE	√	√				Czeczuga, 1980
Umbilicaria arctica	Umbilicariaceae	L		√				Czeczuga & Olech, 1990
Umbilicaria decussata	Umbilicariaceae	L	√	√				Czeczuga & Olech, 1990
Umbilicaria rigida	Umbilicariaceae	L		√				Czeczuga & Alstrup, 1987
Umbilicaria vellea	Umbilicariaceae	L	√	√				Czeczuga & Olech, 1990

Species	Family	Group	Carotene series					Reference
			α-C	β-C	γ-C	δ-C	ε-C	
Undaria pinnatifida	Alariaceae	A		√				Okuda & Ukegawa, 1977
Urtica dioica	Urticaceae	D		√				Kudritsata et al., 1987
Usnea glabrata	Parmeliaceae	L	√	√				Czeczuga et al., 1989
Usnea sulphurea	Parmeliaceae	L	√					Czeczuga & Olech, 1990
Vaccinium corymbosum	Ericaceae	D	√	√				Bureau & Bushway, 1986
Vaccinium macrocarpon	Ericaceae	D	√	√				Heinonen et al., 1989
Vacuolaria virescens	Vacuolariaceae	A		√				Fiksdahl et al., 1984a
Verbena officinalis	Verbenaceae	D		√				Winde et al., 1961
Vernonia baccharoides	Asteraceae	D		√				Ugaz & Fort, 1984
Verticillium agaricinum	Hyphomycetes	FU		√				Valadon & Mummery, 1974
Viburnum opulus	Caprifoliaceae	D		√				Shapiro et al., 1992
Viscum album	Loranthaceae	D		√				Neamtu & Bodea, 1970 Cornelia & Stirban, 1976
Vitis vinifera	Vitaceae	D	√	√	√			Heinonen et al., 1989 Zherebin & Kolesnik, 1984
Zea mays	Poaceae	M		√				Rao, 1967

Group: A = Algae, B = Bacteria and allies, D = Dicotyledons, FU = Fungi, L = Lichens, FE = Ferns and allies, FR = Frogs, G = Gymnosperms, I = Insects, M = Monocotydedons, and S = Animals of the sea (annelids, crabs, echinodermates, fishes, mollusks, prawns, shellfishes, sponges and starfishes).
Carotene series: α-C = α-carotene, β-C = β-carotene, γ-C = γ-carotene, δ-C = δ-carotene, and ε-C = ε-carotene.

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