Progress in the Chemistry of Organic Natural Products

78

Fortschritte der Chemie organischer Naturstoffe

Progress in the Chemistry of Organic Natural Products

Founded by
L. Zechmeister

Edited by
W. Herz, H. Falk,
G. W. Kirby, R. E. Moore,
and Ch. Tamm

Authors:
A. Akhila, G. Adam, K. Rani,
J. Schmidt, and B. Schneider

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Prof. W. HERZ, Department of Chemistry,
The Florida State University, Tallahassee, Florida, U.S.A.

Prof. Dr. H. FALK, Institut für Chemie,
Johannes-Kepler-Universität, Linz, Austria

Prof. G. W. KIRBY, Chemistry Department,
The University of Glasgow, Glasgow, Scotland

Prof. R. E. MOORE, Department of Chemistry,
University of Hawaii at Manoa, Honolulu, Hawaii, U.S.A.

Prof. Dr. CH. TAMM, Institut für Organische Chemie der Universität Basel,
Basel, Switzerland

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List of Contributors

ADAM, Prof. Dr. G., Department of Natural Products Chemistry, Institute of Plant Biochemistry, D-06120 Halle (Saale), Germany

AKHILA, Dr. A., Central Institute of Medicinal and Aromatic Plants, P.O. CIMAP, Lucknow 226 015, India

RANI, Dr. K., Central Institute of Medicinal and Aromatic Plants, P.O. CIMAP, Lucknow 226 015, India

SCHMIDT, Dr. J., Department of Natural Products Chemistry, Institute of Plant Biochemistry, D-06120 Halle (Saale), Germany

SCHNEIDER, Dr. B., Research Group Biosynthesis/NMR, Max Planck Institute for Chemical Ecology, D-07745 Jena, Germany

Contents

Brassinosteroids

G. ADAM[1], J. SCHMIDT[1], and B. SCHNEIDER[2]
[1] Institute of Plant Biochemistry, Halle/S., Germany
[2] Max-Planck-Institute for Chemical Ecology, Jena, Germany

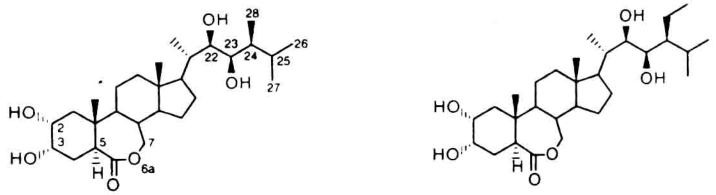
Contents

1. Introduction

It was in 1979 when GROVE *et al.* isolated from pollen of rape (*Brassica napus*) a highly active plant growth promoter, named it brassinolide and elucidated its structure as (22*R*,23*R*,24*S*)-2α,3α,22,23-tetrahydroxy-24-methyl-B-homo-6a-oxa-5α-cholestan-6-one (**1**) by spectroscopic methods including X-ray analysis (*1*). The original structural features of this compound and its unique high biological activity at very low concentrations stimulated intense research activities in many laboratories. Such efforts were directed towards the search for similar compounds in the plant kingdom, their chemical synthesis, biochemistry and biological mode of action leading up to their practical application in agriculture and horticulture. As a result of this interdisciplinary and rapidly processing research, brassinosteroids can nowadays be regarded as a new class of plant hormones with ubiquitous occurrence in the plant kingdom. Especially, recent molecular biological studies demonstrated their essential role for normal plant growth and development. A series of reviews have been published (*2–11*). Whereas the first book on brassinosteroid research covers developments up to 1990 (*12*), two up-to-date publications about this topic have appeared very recently (*13*, *14*). The present article covers the literature up to December 1998 with special consideration of phytochemical, analytical and biochemical aspects.

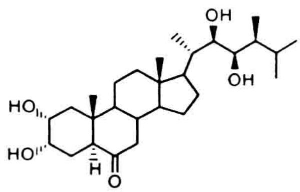
2. Natural Occurrence and Distribution

Till now more than 40 members of the brassinosteroid family including conjugates could be structurally identified (Fig. 1, *1*, *15–89*). They have been found in a large variety of higher plants and could be detected in more than 50 species (*3*, *5–10*, *12*, *13*, *20*). Most brassinosteroids described so far have been isolated from plants belonging to the angiosperms and within this subdivision mainly in the class of the dicots, but have also been found in some gymnosperms (Fig. 2).

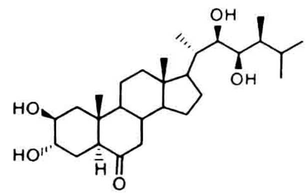


Brassinolide (1) **28-Homobrassinolide (2)**

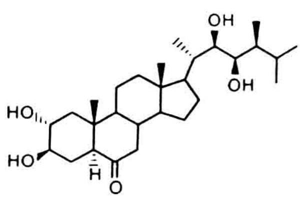
Fig. 1. Structures of brassinosteroids from plants



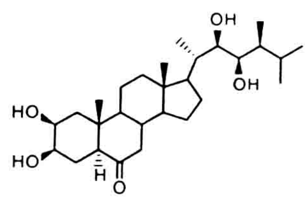
Castasterone (3)



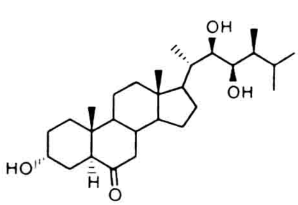
2-Epicastasterone (4)



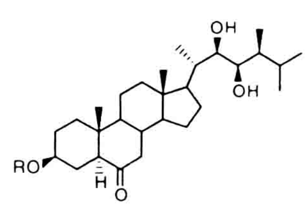
3-Epicastasterone (5)



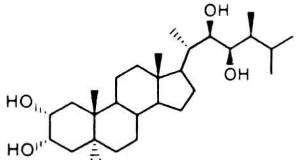
2,3-Diepicastasterone (6)



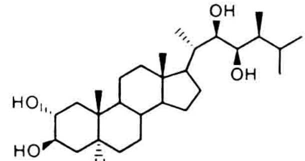
Typhasterol (7)



Teasterone (8) : R = H
Teasterone-3-laurate (9) : R = $CO(CH_2)_{10}CH_3$
Teasterone-3-myristate (10) : R = $CO(CH_2)_{12}CH_3$

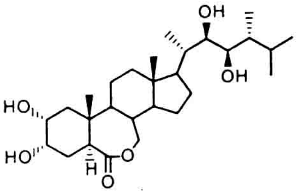


6-Deoxocastasterone (11)

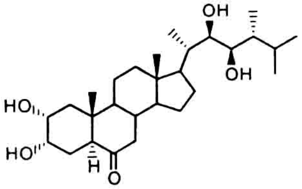


3-Epi-6-deoxocastasterone (12)

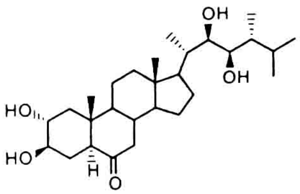
Fig. 1 *(continued)*



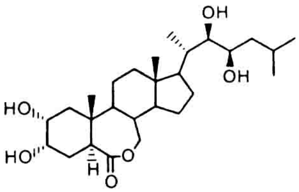
24-Epibrassinolide (13)



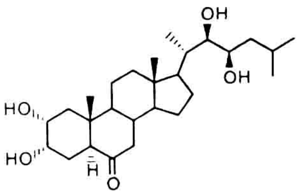
24-Epicastasterone (14)



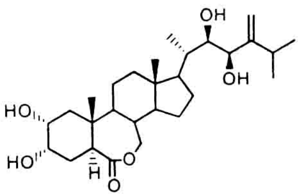
3,24-Diepicastasterone (15)



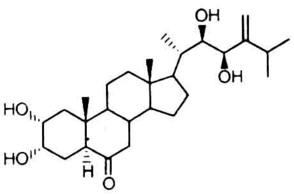
28-Norbrassinolide (16)



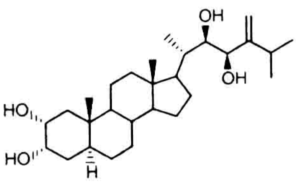
28-Norcastasterone (17)



Dolicholide (18)

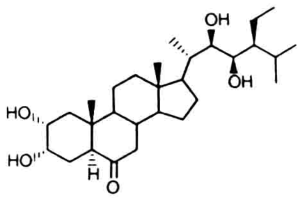


Dolichosterone (19)

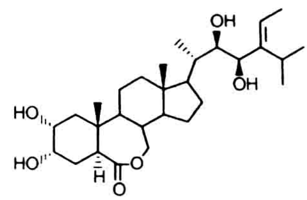


6-Deoxodolichosterone (20)

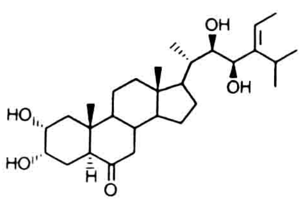
Fig. 1 *(continued)*



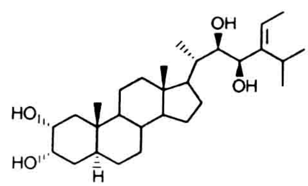
28-Homocastasterone (21)



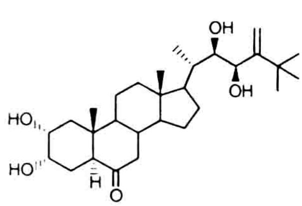
28-Homodolicholide (22)



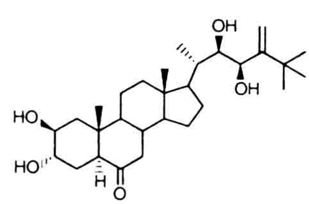
28-Homodolichosterone (23)



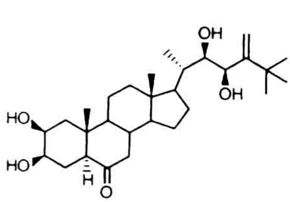
6-Deoxo-28-homodolichosterone (24)



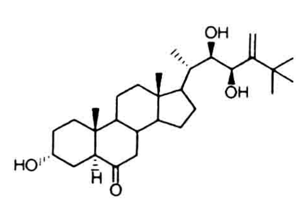
25-Methyldolichosterone (25)



2-Epi-25-methyldolichosterone (26)

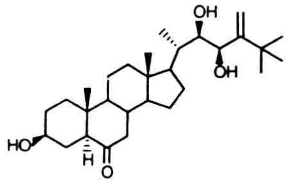


2,3-Diepi-25-methyldolichosterone (27)

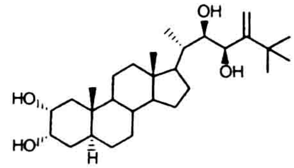


2-Deoxy-25-methyldolichosterone (28)

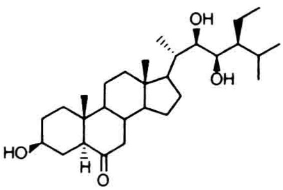
Fig. 1 *(continued)*



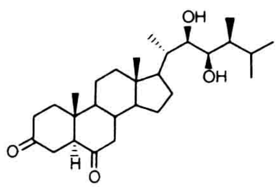
2-Epi-2-deoxy-25-methyldolichosterone (29)



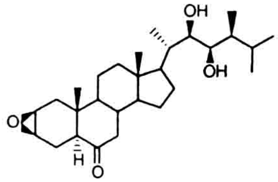
6-Deoxo-25-methyldolichosterone (30)



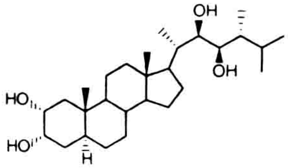
28-Homoteasterone (31)



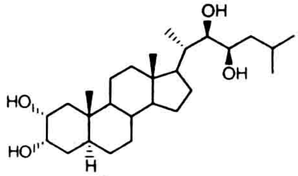
3-Dehydroteasterone (32)



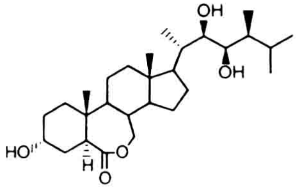
Secasterone (33)



6-Deoxo-24-epicastasterone (34)

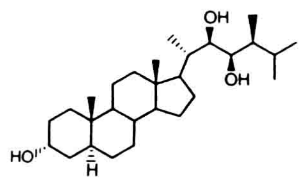


6-Deoxo-28-norcastasterone (35)

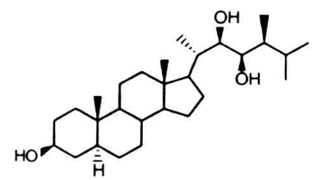


2-Deoxybrassinolide (36)

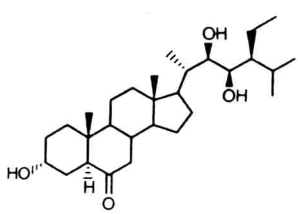
Fig. 1 *(continued)*



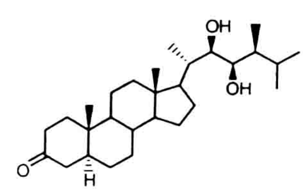
6-Deoxotyphasterol (37)



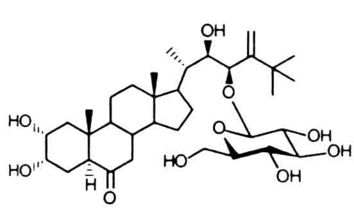
6-Deoxoteasterone (38)



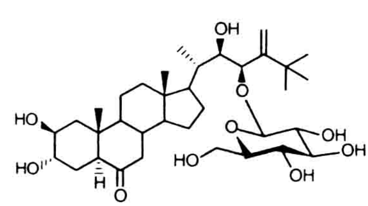
28-Homotyphasterol (39)



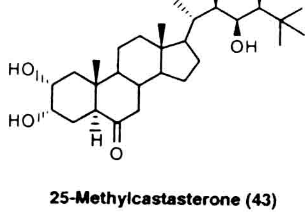
3-Dehydro-6-deoxoteasterone (40)



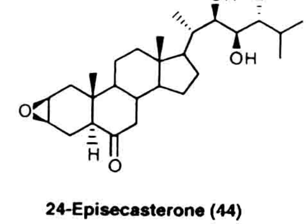
23-O-β-D-Glucopyranosyl-25-methyldolichosterone (41)



23-O-β-D-Glucopyranosyl-2-epi-25-methyldolichosterone (42)



25-Methylcastasterone (43)



24-Episecasterone (44)

Fig. 1 *(continued)*

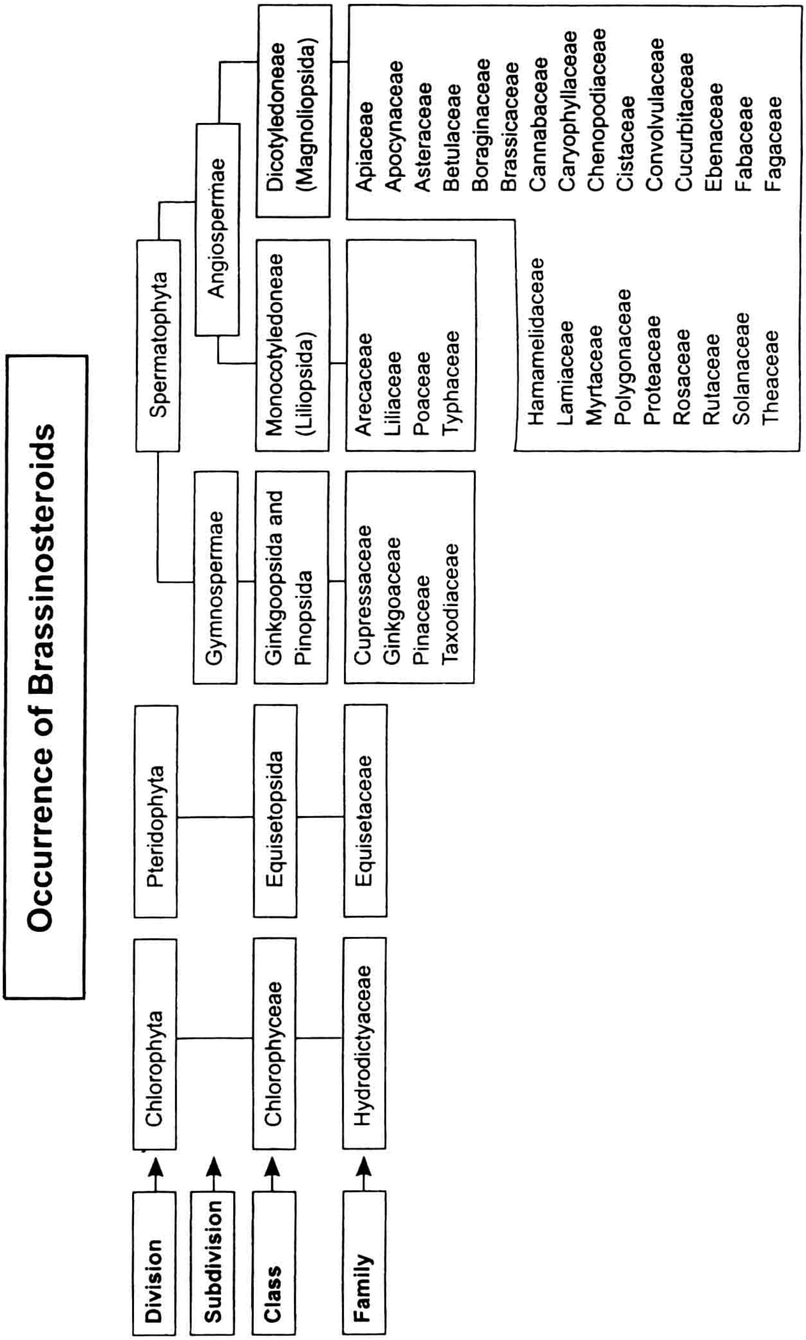


Fig. 2. Distribution of brassinosteroids in the plant kingdom

Table 1. *Natural occurrence of brassinosteroids*

Plant source	Plant family	Plant part(s)	Brassinosteroids	Ref.
Alnus glutinosa (L.) Gaertn.	Betulaceae	pollen	**1, 3**	*(15)*
Apium graveolens L.	Apiaceae	seeds	**36**	*(16)*
Arabidopsis thaliana (L.) Heynh.	Brassicaceae	shoots	**3, 7, 11, 37**	*(17)*
		seeds	**3, 13**	*(18)*
		seeds, siliques	**1, 3, 7, 11, 37, 38**	*(19)*
Banksia grandis Willd.	Proteaceae	pollen	**1, 3**	*(20)*
Beta vulgaris L.	Chenopodiaceae	seeds	**3, 14**	*(21)*
Brassica campestris var. *pekinensis* Lour.	Brassicaceae	seeds, sheath	**1, 2, 3, 16, 17, 21**	*(22–25)*
Brassica napus L.	Brassicaceae	pollen	**1**	*(1)*
Cannabis sativa L.	Cannabaceae	seeds	**3, 8**	*(26, 27)*
Cassia tora L.	Fabaceae	seeds	**1, 3, 7, 8, 17**	*(28)*
Castanea crenata Sieb. et Zucc.	Fagaceae	galls	**1, 3, 11, 17**	*(22, 29–31)*
		shoots	**3, 11**	*(30)*
Catharanthus roseus G. Don	Apocynaceae	culture cells	**1, 3, 7, 8, 11, 37, 38**	*(32–34)*
Cistus hirsutus Theill.	Cistaceae	pollen	**1, 3**	*(20)*
Citrus sinensis Osbeck	Rutaceae	pollen	**1, 3**	*(35)*
Citrus unshiu Marcov.	Rutaceae	pollen	**1, 3, 7, 8**	*(20, 36)*
Cryptomeria japonica D. Don.	Taxodiaceae	pollen, anthers	**7, 18, 32**	*(20, 37)*
Cucumis sativus L.	Cucurbitaceae	seeds	**3**	*(38)*
Cupressus arizonica Greene	Cupressaceae	pollen	**1, 3, 7, 8, 11, 19, 21, 32, 37, 40**	*(39)*
Daucus carota ssp. sativus L.	Apiaceae	seeds	**1, 3, 14**	*(40)*
Diospyros kaki Thunb.	Ebenaceae	seeds	**3**	*(20, 41)*
Distylium racemosum Sieb. et. Zucc.	Hamamelidaceae	galls	**3, 17**	*(22)*
		leaves	**1, 3, 16, 17**	*(24, 42)*
Dolichos lablab L.	Fabaceae	seeds	**1, 3, 11, 18, 19, 20, 22, 23**	*(43–46)*
Echium plantagineum L.	Boraginaceae	pollen	**1**	*(20)*

Table 1 *(continued)*

Plant source	Plant family	Plant part(s)	Brassinosteroids	Ref.
Equisetum arvense L.	Equisetaceae	strobilus	**3, 16, 17, 19**	*(47)*
Eriobotrya japonica Lindl.	Rosaceae	flower buds	**3**	*(20)*
Erythronium japonicum Decne	Liliaceae	pollen, anthers	**7**	*(48)*
Eucalyptus calophylla R. Br.	Myrtaceae	pollen	**1**	*(20)*
Eucalyptus marginata Sn.	Myrtaceae	pollen	**19**	*(20)*
Fagopyrum esculentum Moench	Polygonaceae	pollen	**1, 3**	*(49)*
Ginkgo biloba L.	Ginkgoaceae	seeds	**8**	*(50)*
Gypsophila perfoliata L.	Caryophyllaceae	seeds	**13**	*(51)*
Helianthus annuus L.	Asteraceae	pollen	**1, 3, 17**	*(52)*
Hydrodictyon reticulatum (L.) Lagerheim	Hydrodictyaceae	green alga	**14, 21**	*(53)*
Lilium elegans Thunb.	Liliaceae	pollen	**1, 3, 7, 8**	*(54)*
Lilium longiflorum Thunb.	Liliaceae	anthers	**1, 3, 7, 9, 10, 32**	*(36, 42, 55)*
		pollen	**9, 10**	*(56)*
Lolium perenne L.	Poaceae	pollen	**43**	*(57)*
Lycopersicon esculentum Mill.	Solanaceae	shoots	**3, 11, 17**	*(58)*
Lychnis viscaria L.	Caryophyllaceae	seeds	**14, 44**	*(59)*
Ornithopus sativus Brot.	Fabaceae	seeds	**3, 14**	*(60)*
		shoots	**3, 11, 14, 34, 35**	*(61)*
Oryza sativa L.	Poaceae	shoots	**1, 3, 19**	*(62)*
		bran	**11, 31, 39**	*(63)*
		seeds	**3, 8, 11**	*(64)*
Perilla frutescens Britton.	Lamiaceae	seeds	**3**	*(64)*
Phalaris canariensis L.	Poaceae	seeds	**3, 8**	*(65)*
Pharbitis purpurea Voigt	Convolvulaceae	seeds	**3, 17**	*(66)*
Phaseolus vulgaris L.	Fabaceae	seeds	**1, 3–8, 11, 12, 15, 18–20, 24–30, 41, 42**	*(67–72)*
Phoenix dactylifera L.	Arecaceae	pollen grains	**14**	*(73)*

References, pp. 36–46