

Progress in the Chemistry of
Organic Natural Products

Fortschritte der Chemie
organischer Naturstoffe

Progress in the
Chemistry of Organic
Natural Products

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Brassinosteroids

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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*)-2 α ,3 α ,22,23-tetrahydroxy-24-methyl-B-homo-6 α -oxa-5 α -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).

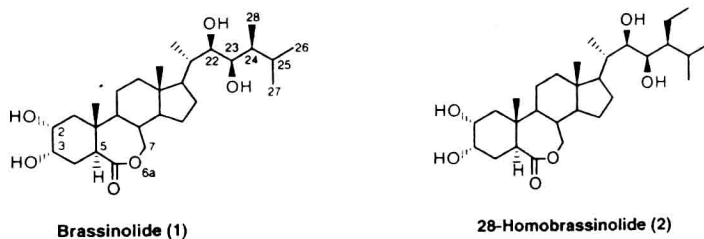
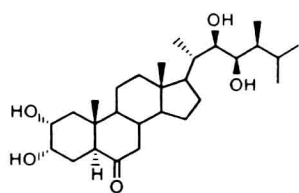
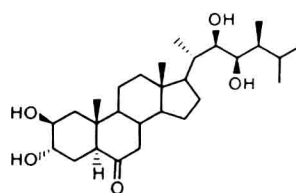
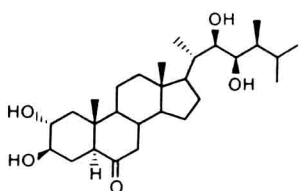
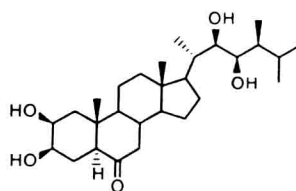
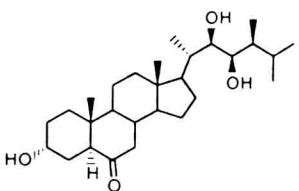
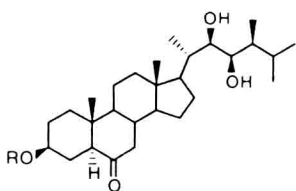
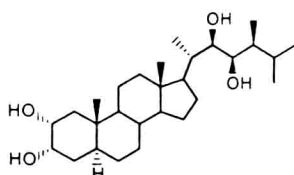
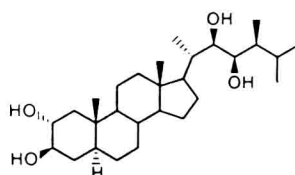


Fig. 1. Structures of brassinosteroids from plants

**Castasterone (3)****2-Epicasterone (4)****3-Epicasterone (5)****2,3-Diepicasterone (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-Deoxocasterone (11)****3-Epi-6-deoxocasterone (12)****Fig. 1 (continued)**

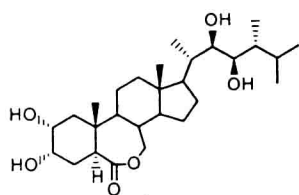
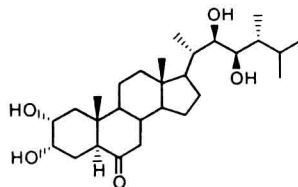
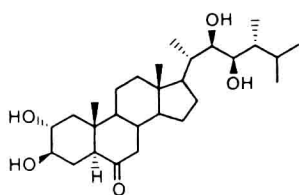
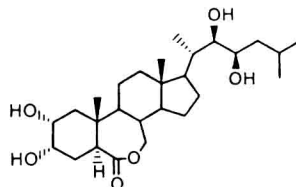
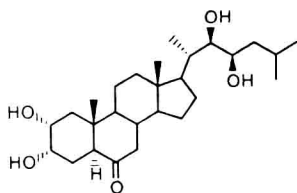
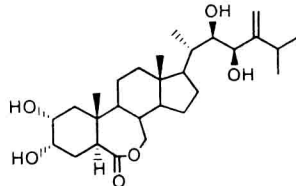
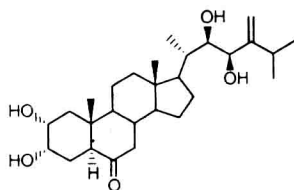
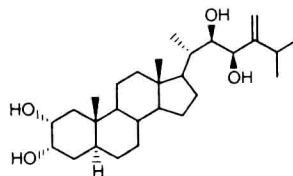
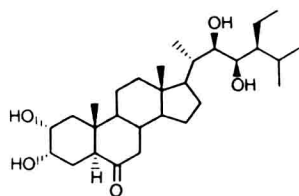
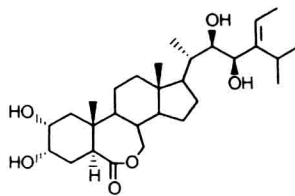
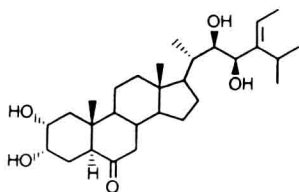
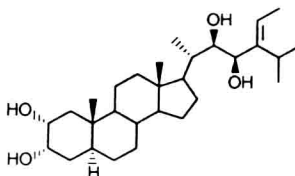
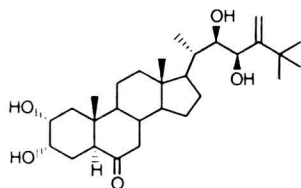
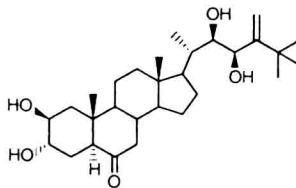
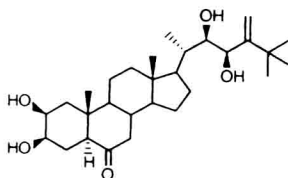
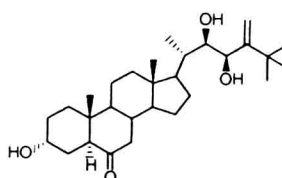
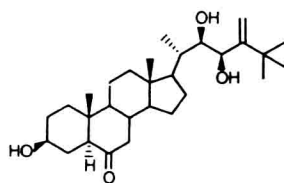
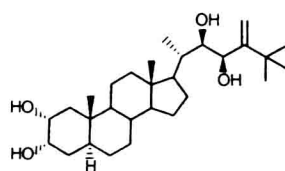
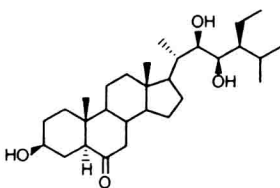
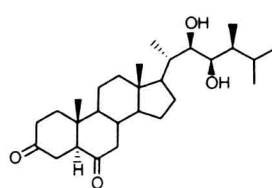
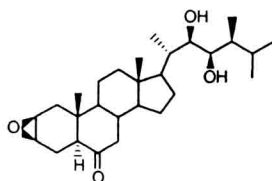
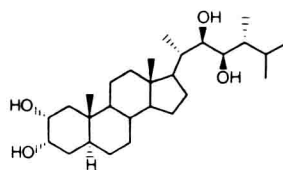
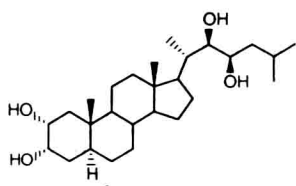
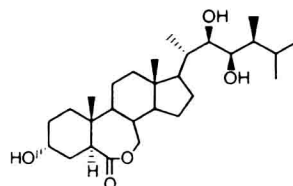
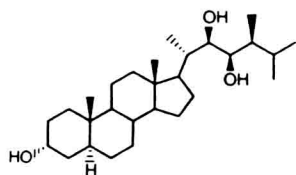
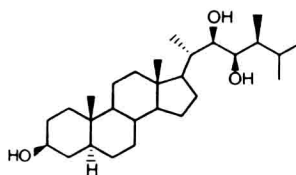
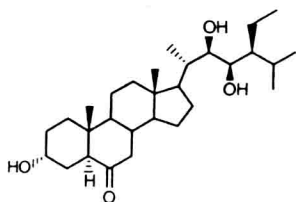
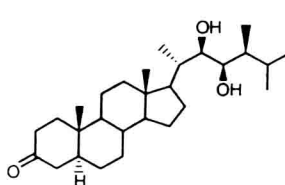
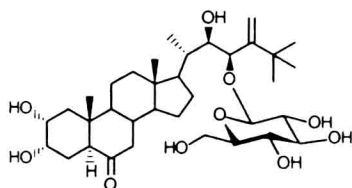
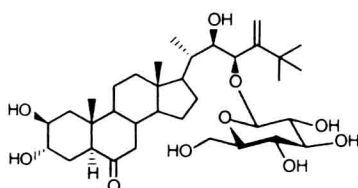
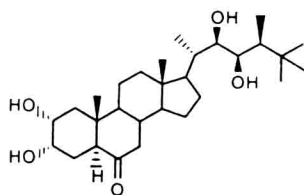
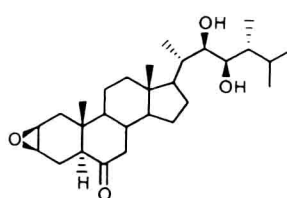
**24-Epibrassinolide (13)****24-Epicastasterone (14)****3,24-Diepicastasterone (15)****28-Norbrassinolide (16)****28-Norcastasterone (17)****Dolicholide (18)****Dolichosterone (19)****6-Deoxodolichosterone (20)**

Fig. 1 (continued)

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**28-Homocasterone (21)****28-Homodolicholide (22)****28-Homodolichosterone (23)****6-Deoxy-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-Deoxy-25-methyldolichosterone (30)****28-Homoteasterone (31)****3-Dehydroteasterone (32)****Secasterone (33)****6-Deoxy-24-epicastasterone (34)****6-Deoxy-28-norcastasterone (35)****2-Deoxybrassinolide (36)****Fig. 1 (continued)**

**6-Deoxytyphasterol (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-Methylcasterone (43)****24-Episcasterone (44)***Fig. 1 (continued)*

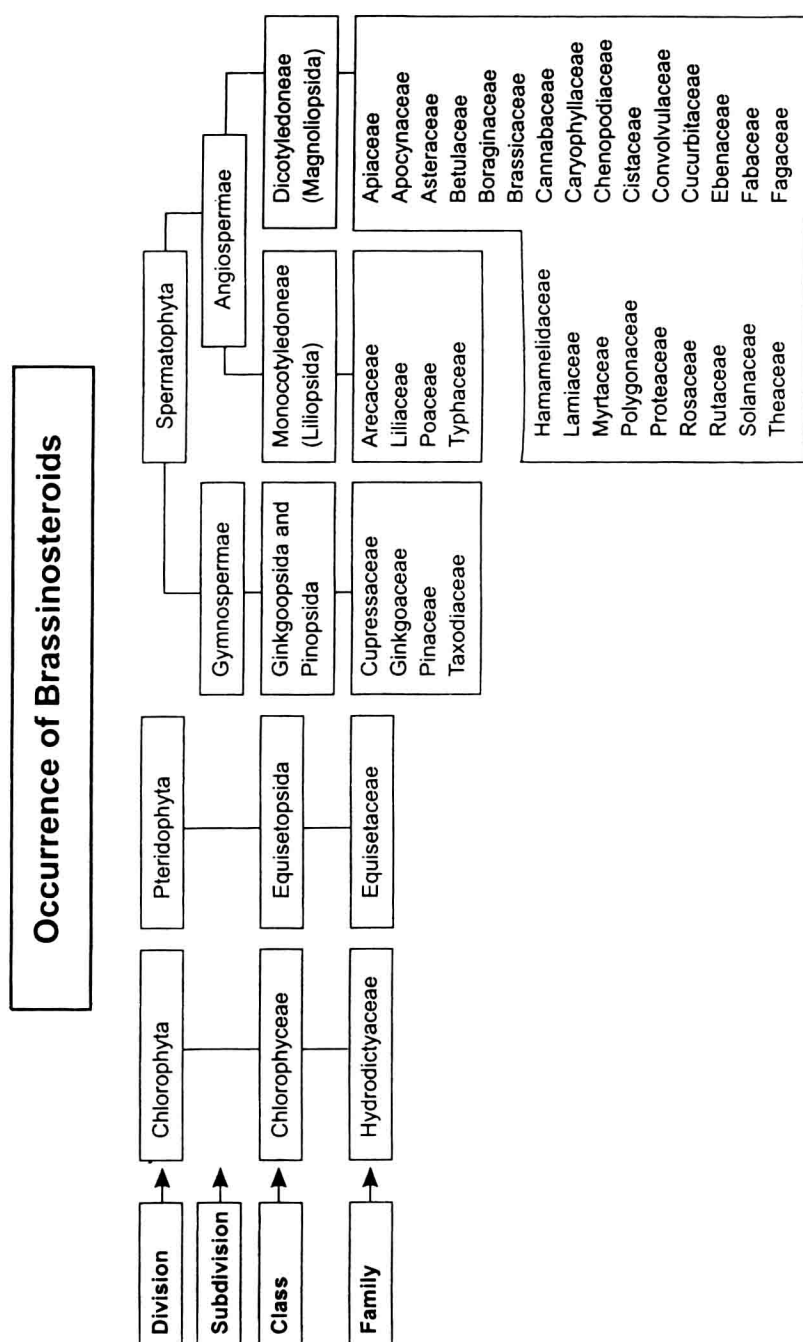


Fig. 2. Distribution of brassinosteroids in the plant kingdom

Table 1. Natural occurrence of brassinosteroids

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

Table 1 (continued)

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

References, pp. 36-46