

REVIEW

TRYPTAMINE AND RELATED COMPOUNDS IN PLANTS

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Key Word Index—Fungi; Spermatophyta; tryptamine; serotonin; bufotenine; psilocybin; gramine; amines; review.

Abstract—The occurrence of the tryptamines and related compounds in fungi and higher plants is listed on a taxonomic basis. Several of these amines have considerable physiological activity in higher animals.

The indole amines which are derived from the amino acid tryptophan occur in a wide variety of plant families, but are especially common in the Gramineae and Leguminosae. The biosynthesis and metabolism of these amines has been reviewed in ref. [110]. Tryptamine is likely to be the precursor of the plant growth hormone indole acetic acid, at least in some plants [23, 111]. The tryptamines are also the precursors of the tricyclic β -carboline alkaloids formed by condensation with a one- or two-carbon moiety [112].

The psychoactive indole amines dimethyltryptamine, bufotenine and methoxy *N*-dimethyltryptamine are constituents of hallucinatory snuffs and decoctions used by various ethnic groups. These are derived from species of *Piptadenia*, *Banisteriopsis* and *Virola*, and *Mimosa hostilis* and *Lespedeza bicolor*, especially in parts of South America [4, 9, 12, 14, 73, 113, 114]. Dimethyltryptamine is apparently inactive orally probably because it is metabolized by a monoamine oxidase and it is only effective when taken parenterally or as snuff. However, the co-occurrence of the β -carboline alkaloids may potentiate oral activity of dimethyltryptamine since these alkaloids are inhibitors of monoamine oxidase [9]. Psilocybin, a unique phosphorylated indole amine, and psilocin, are also hallucinatory amines found in several genera of basidiomycetes growing in Europe, Central and North America, and South East Asia [8].

Ingestion of large amounts of the tryptamines may be harmful to humans and to some animals. For instance, there may be a connection between the incidence of myocardial fibrosis in West Africa and the high intake of plantains (bananas, *Musa*) in this region, attributable to

the high level of 5-hydroxytryptamine (5-HT) in this food [115]. Cattle in Australia fed on pastures of *Phalaris arundinacea* develop a disease known as Phalaris staggers. This is probably due to the high levels of tryptamines present [39]. In Canada this grass is associated with bovine pulmonary emphysema [38]. In addition, gramine reduces adult weight and is a feeding inhibitor for grasshoppers [34].

The excretion of 5-hydroxyindoleacetic acid (5-HIAA) is used in the clinical diagnosis of carcinoid tumour. 5-HIAA is an oxidation product of 5-HT which occurs widely in food plants. A diet free of 5-HT containing foods is therefore necessary before the diagnosis of carcinoid tumour by this technique [116]. The occurrence of tryptamine and 5-HT in food plants has been reviewed in ref [117].

5-HT occurs in the stinging hairs of *Mucuna pruriens* [118], *Girardinia heterophylla* [102] and *Urtica* spp [105, 106] and probably also *Laportea moroides* [103]. It is considered to be one of the active principles in these stings, and is found also in the venoms of several animals [119].

Isolation of tryptamines from plant material may involve extraction of alkaline macerates [Na_2CO_3 or NH_4OH] with CHCl_3 or Et_2O . Purification may also be achieved with cation exchange resins. TLC or PC are used for the separation of complex mixtures with the Salkowski, Ehrlich (*p*-dimethylamino-benzaldehyde or -cinnamaldehyde), Pauly, or Dragendorff chromogenic reagents. The nitrosonaphthol reagent may be used for 5-hydroxyindoles. The tryptamines do not require prior derivatization for separation by GLC.

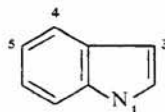
INDOLALKYLAMINES FOUND IN PLANTS

Name	Abbreviation	Position 5	Position 4	Position 3 (side chain)	Position 1
Tryptamine	Try	H	H	$-\text{CH}_2-\text{CH}_2-\text{NH}_2$	H
Methyltryptamine	MeTry	H	H	$-\text{CH}_2-\text{CH}_2-\text{NH}-\text{Me}$	H
Dimethyltryptamine	diMeTry	H	H	$-\text{CH}_2-\text{CH}_2-\text{N}-(\text{Me})_2$	H*
5-Hydroxytryptamine (serotonin)	Ser	OH	H	$-\text{CH}_2-\text{CH}_2-\text{NH}_2$	H

* Psychoactive.

Continued

Name	Abbreviation	Position 5	Position 4	Position 3 (side chain)	Position 1
Methylserotonin	MeSer	OH	H	$-\text{CH}_2-\text{CH}_2-\text{NHMe}$	H
Bufotenine	Buf	OH	H	$-\text{CH}_2-\text{CH}_2-\text{N}(\text{Me})_2$	H*
Dehydrobufotenine	dhBuf	OH	H	$-\text{CH}=\text{CH}-\text{N}(\text{Me})_2$	H
Bufotenidine	Bufd	O ⁻	H	$-\text{CH}_2-\text{CH}_2-\text{N}(\text{Me})_3$	H
Methoxytryptamine	MeOTry	MeO	H	$-\text{CH}_2-\text{CH}_2-\text{NH}_2$	H
Methoxy <i>N</i> -methyltryptamine	MeOMeTry	MeO	H	$-\text{CH}_2-\text{CH}_2-\text{NHMe}$	H
Methoxy <i>N</i> -dimethyltryptamine	MeOdiMeTry	MeO	H	$-\text{CH}_2-\text{CH}_2-\text{N}(\text{Me})_2$	H*
Psilocin	Psilocin	H	OH	$-\text{CH}_2-\text{CH}_2-\text{N}(\text{Me})_2$	H*
Psilocybin	Psilocybin	H	HPO ₄ ⁻	$-\text{CH}_2-\text{CH}_2-\text{NH}(\text{Me})_2$	H*
Aminomethylindole	AMI	H	H	$-\text{CH}_2-\text{NH}_2$	H
Methylaminomethylindole	MAMI	H	H	$-\text{CH}_2-\text{NH}-\text{Me}$	H
Gramine	Gra	H	H	$-\text{CH}_2-\text{N}(\text{Me})_2$	H
— <i>N</i> -Oxide	Nox	various	H	$-\text{CH}_2-\text{CH}_2-\text{N}(\text{Me})_2 \rightarrow \text{O}$	H
—Methohydroxide	MeOH	various	H	$-\text{CH}_2-\text{CH}_2-\text{N}(\text{Me})_3\text{OH}^-$	H
Lespedamine	Lespedamine	H	H	$-\text{CH}_2-\text{CH}_2\text{N}(\text{Me})_2$	OMe



Family	Species	Amine	Tissue†	Ref.
FUNGI				
	<i>Claviceps purpurea</i> (Fr.)	Try		[1]
	Tulasne			
	<i>Amanita</i> spp.	Ser; MeSer; diMeTry		[2-4]
		Buf; BufNox;		
		MeOdiMeTry		
	<i>Boletus erythropus</i>	Try		[5]
	<i>Sarcodon imbricatum</i>	Try		[5]
	<i>Coprinus</i> spp.	Try		[6, 7]
	<i>Panaeolus</i> spp.	Try		
	<i>Psilocybe</i> spp.	Ser		
	<i>Conocybe</i> spp.	Psilocybin		[3, 4, 8, 9]
	<i>Stropharia</i> spp.	Psilocin		
HIGHER PLANTS				
Aceraceae	<i>Acer rubrum</i> L.	Gra	(Fr)	[10]
	<i>Acer saccharinum</i> L.	Gra	(L)	[11]
Aizoaceae	<i>Delosperma</i> sp.	MeTry; diMeTry		[4, 12]
Apocynaceae	<i>Prestonia amazonica</i> ?	diMeTry		[13, cf. 9, 14]
Araceae	<i>Symplocarpus foetidus</i> Nutt.	Ser	(L)	[15]
Bromeliaceae	<i>Ananas sativus</i> Schult.	Ser	(Fr)	[16]
Caricaceae	<i>Carica papaya</i> L.	Ser		[17]
Chenopodiaceae	<i>Arthrophytum leptocladum</i> M. Pop.	MeTry	(L, S)	[18, 19]
	<i>Arthrophytum wackchanica</i>	MeTry		[20]
	<i>Girgensohnia diptera</i> Bge.	MeTry		[21]
	<i>Hammada leptoclada</i>	MeTry	(L, S)	[22]
Cucurbitaceae	<i>Citrullus vulgaris</i> Schrad.	Try	(Fr)	[23]
Elaeagnaceae	<i>Elaeagnus umbellata</i> Thunb.	Ser	(L, B, Sd)	[24]
	<i>Hippophae rhamnoides</i> L.	Ser	(R)	[25]
Gramineae	<i>Arundinella hirta</i> L.	Ser		[26]
	<i>Arundo donax</i> L.	MeOMeTry; diMeTry;	(L, Fl, Rh)	[27-30]
		diMeTryMeOH; Buf;		
		diMeTryNox; Bufd		
		dhBuf; Gra; GraNox		
		GraMeOH		
	<i>Avena sativa</i> L.	Try	(Sl)	[31]
	<i>Calamagrostis</i> sp.	Ser		[26]
	<i>Hordeum jubatum</i> L.	Gra		[34]

continued overleaf

† Key to the tissue studied. L = leaf; R = root; Fr = fruit; Sd = seed; Sl = seedling; B = bark; Fl = flowers; Rh = rhizomes; S = stem; W = wood.

Family	Species	Amine	Tissue	Ref.
	<i>Hordeum nodosum</i> L.	Gra		[34]
	<i>Hordeum vulgare</i> L.	Try; Ser; MeSer; AMI; MAMI; Gra	(Sl)	[32, 33]
	<i>Imperata cylindrica</i>	Ser		[26]
	<i>Oryza sativa</i> L.	Ser	(Sl)	[35]
	<i>Phalaris arundinacea</i> L.	Try; MeTry; diMeTry; MeOTry; MeOMeTry; MeOdiMeTry; Buf; Gra	(L)	[36-39]
	<i>Phalaris tuberosa</i> L.	diMeTry; MeOdiMeTry; diMeTryMeOH; MeOdiMeTryMeOH; Buf; Gra	(L, Sl)	[40-43]
	<i>Phyllostachys reticulata</i>	Ser		[26]
	<i>Triticum vulgare</i> Vill.	Try	(Sl)	[31]
	<i>Zea mays</i> L.	Try; CoumarylTry; FerulylTry	(Sd, Sl)	[31, 44]
Juglandaceae	<i>Zizania caudiflora</i>	Ser		[26]
Lauraceae	<i>Juglans regia</i> L.	Ser	(Fr)	[45]
	<i>Nectandra megapotamica</i> (Sprg.) C. & H.	MeTry	(B)	[46]
Leguminosae	<i>Persea americana</i> Mill.	Ser	(Fr)	[47]
	<i>Acacia</i> spp.	Try; MeTry; diMeTryNox;	(L, S, Fl, B)	[28, 48-56]
	<i>Albizia julibrissin</i> Durazz.	Ser	(L)	[57]
	<i>Burkea africana</i> Hook.	Try	(B)	[58, 59]
	<i>Desmodium gangeticum</i> DC.	Try; diMeTry; diMeTryNox; Gra; MeSer; Buf; BufNox; MeOMeTry;		
	<i>Desmodium gyrans</i> DC.	MeOdiMeTry;	(L, R, S, Sd)	[28, 60-66]
	<i>Desmodium pulchellum</i> Benth. ex Baker	MeOdiMeTryNox; diMeTryMeOH; MeOdiMeTryMeOH		
	<i>Desmodium tiliacifolium</i> G. Don	Try	(W)	[67]
	<i>Desmodium triflorum</i> DC.	Ser	(L, Fr)	[68]
	<i>Dicorynia guianensis</i> Amsh.	diMeTry; diMeTryNox; Buf; MeOdiMeTry; MeOdiMeTryNox; Lespedamine	(L, R)	[69, 70]
	<i>Griffonia simplicifolia</i>			
	<i>Lespedeza bicolor</i> Turcz.			
	<i>Lupinus hartwegii</i> Hindl.	Gra	(L, S)	[71, 72]
	<i>Lupinus hispanicus</i> Boss. & Reut.			
	<i>Lupinus luteus</i> L.	diMeTry	(R)	[11]
	<i>Mimosa hostilis</i> Benth.	diMeTry	(B)	[73]
	<i>Mimosa verrucosa</i>	Ser; MeOdiMeTry;	(L, S, Fr)	[74, 75]
	<i>Mucuna pruriens</i> DC.	diMeTry; Buf; diMeTryNox		
	<i>Petalostylis labicheoides</i> Benth.	Try; diMeTry	(L, S)	[76]
	<i>Phaseolus vulgaris</i> L.	Ser	(L)	[57]
	<i>Piptadenia</i> spp. (<i>Anadenanthera</i>)	Try; MeTry; diMeTry diMeTryNox; Buf; BufNox; Ser; MeSer; MeOMeTry; MeOdiMeTry	(L, B, Sd)	[11, 77-82]
	<i>Pisum sativum</i> L.	Ser	(L)	[57]
	<i>Prosopis juliflora</i> DC.	Try; Ser		[83]
	<i>Prosopis alba</i> Gris.	Try	(L)	[84]
	<i>Prosopis nigra</i>	Try; AcetylTry		[85]
	<i>Samanea saman</i> Merr.	Ser	(L)	[57]
Malpighiaceae	<i>Banisteriopsis argentea</i> Spring ex Juss.	diMeTry; diMeTryNox	(L)	[86]
	<i>Banisteriopsis rusbyana</i> ex Small	MeTry; diMeTry; Buf; MeOdiMeTry	(L)	[87, 88]
Malvaceae	<i>Gossypium hirsutum</i> L.	Ser	(Fr)	[15]
Musaceae	<i>Musa sapientum</i> L.	Ser	(Fr)	[47, 89-91]
Myristicaceae	<i>Virola</i> spp.	MeTry; diMeTry; MeOTry; MeOMeTry MeOdiMeTry	(L, R, B, Fl)	[81, 92]
	<i>Gymnacranthera paniculata</i> (A. DC.) Warb.	1.5-diMeOGra		[94]
Passifloraceae	<i>Passiflora quadrangularis</i> L.	Ser	(L)	[57]
	<i>Passiflora edulis</i> Sims	Try; AcetylTry	(L)	[95]

Continued

Family	Species	Amine	Tissue	Ref.
Ranunculaceae	<i>Ranunculus sceleratus</i> L.	Ser		[96]
Rosaceae	<i>Prunus</i> spp.	Try; Ser	(Fr. L)	[47, 97]
Rubiaceae	<i>Oldenlandia affinis</i> DC.	Ser		[98]
	<i>Psychotria psychotriaefolia</i> (Seem.) Stand.	diMeTry		[99, cf. 73]
	<i>Psychotria viridis</i> R. & P.	diMeTry		[73]
Rutaceae	<i>Citrus sinensis</i> Osbeck	Try	(Fr)	[47]
	<i>Dictyoloma incanescens</i> DC	MeOdiMeTry	(B)	[11]
	<i>Vepris ampody</i> H. Perr.	diMeTry		[100]
Solanaceae	<i>Lycopersicon esculentum</i> Mill.	Try; Ser	(L, S, Fr)	[31]
	<i>Solanum melongena</i> L.	Try; Ser	(Fr)	[47]
	<i>Nicotiana tabacum</i> L.	Try	(L)	[31]
Tovariaceae	<i>Tovaria pendula</i> Ruiz. & Pavon.	Ser	(L, S)	[101]
Urticaceae	<i>Girardinia heterophylla</i> (Decne)	Ser	(L)	[102]
	<i>Laportea moroides</i>	Ser?		[103]
	<i>Urtica dioica</i> L.	Ser	(L)	[104, 107]
	<i>Urtica pilulifera</i> L.	Ser; Buf	(L, S)	[105, 106]
	<i>Urtica parviflora</i> Roxb.	Ser	(L)	[108]
Zygophyllaceae	<i>Peganum harmala</i>	6-OHTry; Ser	(Sd, Sl)	[109]

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