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ACKNOWLEDGMENTS AND ADDRESSES

Received August 24, 1973, from the *Pharmacy Department, School of Pharmacy, Hebrew University, Jerusalem, Israel.*

Accepted for publication June 18, 1974.

Abstracted in part from a thesis submitted by M. Friedman to the Hebrew University of Jerusalem in partial fulfillment of the Doctor of Philosophy degree requirements.

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Chemical Constituents of Gentianaceae XIV: Tetraoxygenated and Pentaoxygenated Xanthones of *Swertia purpurascens* Wall.

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Abstract □ The whole plant of *Swertia purpurascens* Wall. (Gentianaceae) has been shown to contain five tetraoxygenated and three pentaoxygenated xanthones. These are identified as 1,5,8-trihydroxy-3-methoxyxanthone, 1,3,8-trihydroxy-5-methoxyxanthone, 1-hydroxy-3,7,8-trimethoxyxanthone, 1,3,7,8-tetrahydroxyxanthone, 1,3,5,8-tetrahydroxyxanthone, and 1-hydroxy-3,4,7,8-tetramethoxyxanthone by chemical and spectral evidence. Additionally, the crude mixture of natural xanthones has been shown to include two partially methylated pentaoxygenated xanthones as minor entities, which yield 1-hydroxy-3,4,7,8-tetramethoxyxanthone and 1-hydroxy-3,4,5,8-tetramethoxyxanthone on methylation. This is the first time that pentaoxygenated xanthones have been found in a member of the genus *Swertia*. 1-Hydroxy-3,4,7,8-tetramethoxyxanthone was previously known only as a synthetic compound. The total xanthones of *S. purpurascens* produce significant CNS stimulant actions, consistent with some therapeutic uses of the plant extract in the Indian system of medicine. The chemotaxonomic significance of the cooccurrence of various biogenetically related chemical characters in a single plant species is appraised.

Keyphrases □ *Swertia purpurascens* Wall. (Gentianaceae)—five tetraoxygenated and three pentaoxygenated xanthones isolated and identified, screened for pharmacological activity □ Gentianaceae—chemical constituents, five tetraoxygenated and three pentaoxygenated xanthones isolated and identified from *S. purpurascens*, screened for pharmacological activity □ Xanthones, tetraoxygenated and pentaoxygenated—isolated and identified from *S. purpurascens*, screened for pharmacological activity □ Medicinal plants—isolation and identification of tetraoxygenated and pentaoxygenated xanthones from *S. purpurascens*, screened for pharmacological activity

Swertia purpurascens Wall. (Gentianaceae) is widely distributed in India in the temperate North Western Himalayas, 1524–3658 m (5000–12,000 ft), from Kashmir to Kumaon. The plant is used in the Indian system of medicine as a substitute for *Swertia chirata* Buch.-Ham. (1).

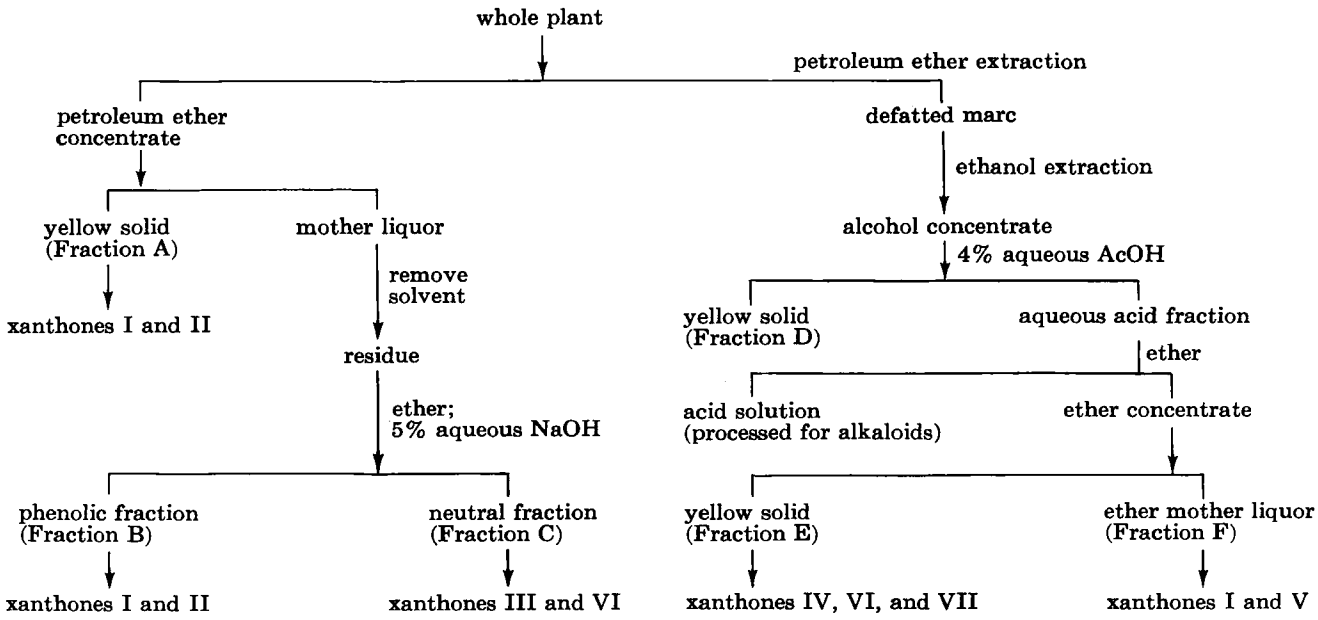
In a recent paper (2), isolation and characterization of three tetraoxygenated xanthone *O*-glucosides from the water-soluble xanthone fraction of this plant were reported. Since xanthone-bearing plants generally elaborate multiple xanthones (3), the earlier investigation has now been complemented by examination of the less polar xanthone fractions of this plant. This study has resulted in the isolation and identification of seven tetra- and pentaoxygenated xanthones, three of which are new naturally occurring compounds.

Another reason for the present investigation was to determine the pharmacological profile of activity of the free xanthones on the central nervous system (CNS) of laboratory animals. It was earlier demonstrated (2–6) that, while polyoxygenated xanthones and a xanthone C-glucoside, mangiferin, produced central stimulant action (mediated *via* monoamine oxidase inhibition) (4–6), the corresponding xanthone *O*-glucosides and related compounds showed definite signs of CNS depressant action (antipsycho-

Table I—Glucoxanthone and Glycoflavones Occurring in the Genera *Swertia* and *Gentiana*[a]

Species	Compound	Reference
S. swertopsis	Mangiferin (VIII), isovitexin (IX), homoorientin (X)	15
S. japonica	Orientin (XI), swertiajaponin (XII), swertisin (XIII)	16
S. purpuracens	Swertisin (XIII)	7
S. chirata	Mangiferin (VIII)	3
G. lutea	Mangiferin (VIII), isovitexin (IX), isoorientin (XIV)	17

[a] *Note added in proof: G. verna* was recently shown to contain mangiferin and isoorientin. [K. Hostettmann and A. Jacotguillarmod, *Helv. Chim. Acta*, **57**, 1155(1974).]



Scheme I—Isolation of tetra- and pentaoxygenated xanthones of S. purpurascens

tic action) (2–4, 6) in albino mice and rats. It was therefore thought worthwhile to study the pharmacological profile of activity of the total free xanthones of *S. purpurascens*.

The details of the chemical and pharmacological evaluations are incorporated in this paper. Additionally, the chemotaxonomic significance of the cooccurrence of several polyoxygenated xanthones, xanthone *O*-glucosides (2), and a glucoflavone (swertisin) (7) in a single plant species is appraised.

EXPERIMENTAL[1]

Extraction of *S. purpurascens*[2]—The isolation of polyoxygenated xanthones[3] from the whole plant of *S. purpurascens* (1 kg) was accomplished following the procedure shown in Scheme I. Dried and milled plant material was continuously extracted in a soxhlet apparatus with petroleum ether (bp 60–80°) and then with ethanol (28 hr each). The two extracts were separately processed.

Isolation of Xanthones from Petroleum Ether Extract—The petroleum ether extract was concentrated (about 150 ml) and the concentrate was kept at room temperature overnight when a yellow solid (7.4 g, Fraction A) separated. The solid was collected by filtration and the mother liquor was evaporated to dryness (13.5 g). A portion of the residue (2.5 g), from the mother liquor was dissolved in ether, and the phenolic and nonphenolic constituents were separated by extraction with aqueous sodium hydroxide (5%, 3 × 30 ml). The alkaline solution, after the usual workup, afforded a brown solid (78 mg, Fraction B). The neutral fraction was obtained as a pale-yellow solid (1.54 g, Fraction C).

Separation of Xanthones from Fraction A—A portion of the solid (1.4 g) was intimately mixed with silica gel (about 10 g) and placed over a silica gel column (20 × 3 cm). The column was eluted with benzene (5 liters), and fractions were collected (100 ml). The middle benzene fractions, on concentration, gave a yellow solid (0.488 g), which was partly soluble in aqueous sodium carbonate (5%). The alkali-insoluble solid was filtered, washed with water, and dried.

Xanthone I (1,5,8-Trihydroxy-3-methoxyxanthone)—The alkali-insoluble solid crystallized from ethanol as shining yellow needles (0.312 g), mp 270–271°. The melting point, mixed melting point, R_f value, and UV, PMR, and mass spectra of the compound were identical with those of authentic 1,5,8-trihydroxy-3-methoxyxanthone (3, 8). The 5,8-dimethyl ether of the xanthone, prepared with ethereal diazomethane, crystallized from ethanol as pale-yellow needles, mp and mixed mp 205°.

Xanthone II (1,3,8-Trihydroxy-5-methoxyxanthone)—The xanthone from the aqueous sodium carbonate-soluble fraction was liberated with hydrochloric acid and extracted with chloroform. The residue (0.102 g) from the chloroform extract crystallized from ethanol as yellow needles, mp 263–265°. The melting point, mixed melting point, R_f value, and UV, PMR, and mass spectra of the compound were identical with those of authentic 1,3,8-trihydroxy-5-methoxyxanthone (3, 8). The 1,3,8-trimethyl ether, prepared with dimethyl sulfate and potassium carbonate in anhydrous acetone (46 hr), crystallized from ethanol as colorless needles, mp 209–210°. The melting point, mixed melting point, and R_f value were identical with those of 1,3,5,8-tetramethoxyxanthone.

Separation of Xanthones from Fraction B—The phenolic constituents (78 mg) showed six major spots with analytical TLC. Preparative layer chromatography of this fraction afforded further crops of xanthones I (41 mg) and II (8 mg). The remaining components of the mixture could not be determined because of their similar R_f values.

Separation of Xanthones from Fraction C—The solid (1.54 g) from Fraction C was dissolved in chloroform and chromatographed over silica gel. Elution was carried out with petroleum ether, benzene, benzene–chloroform (1:1), and chloroform, 3 liters each. Fractions (100 ml) were collected. The later benzene and early benzene–chloroform eluates afforded a mixture of two xanthones, which were separated by preparative layer chromatography using chloroform–benzene–acetic acid (100:40:2) as the solvent.

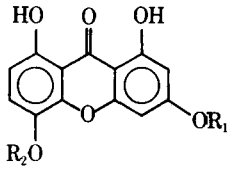
1-Hydroxy-3,7,8-trimethoxyxanthone (Decussatin) (III)—The upper preparative layer zone (R_f 0.6) was eluted with chloroform, and the residue (68 mg) was crystallized from ethanol as yellow needles, mp 148–149°. The melting point, mixed melting point, R_f value, and UV, PMR, and mass spectra of the compound were identical with those of authentic decussatin (3, 8).

1-Hydroxy-3,4,7,8-tetramethoxyxanthone (VI)—The lower preparative layer zone (R_f 0.2), after the usual workup, yielded 1-hydroxy-3,4,7,8-tetramethoxyxanthone as yellow needles (12 mg), mp 188–190°. The melting point, mixed melting point, R_f value, and UV absorption spectrum of the compound were identical with those of an authentic synthetic sample (prepared from decussatin by persulfate oxidation followed by methylation with ethereal diazomethane) of 1-hydroxy-3,4,7,8-tetramethoxyxanthone.

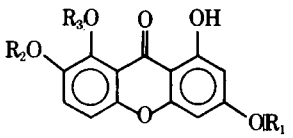
[1] The general directions were reported previously (2).

[2] The plant materials were collected in two lots, in June 1972 and June 1973, by Mr. M. R. Uniyal, Survey of Indian Medicinal Plants Unit, Central Council of Research in Indian Medicine and Homoeopathy, Jogindernagar, Himachal Pradesh. Voucher specimens have been preserved at the Pharmaceutical Chemistry Research Laboratory, Department of Pharmaceutics, Banaras Hindu University.

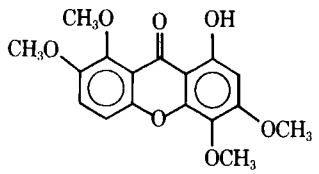
[3] All reported compounds showed satisfactory combustion analyses.



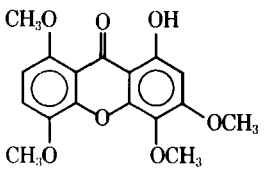
I: $R_1 = CH_3$, $R_2 = H$
II: $R_1 = H$, $R_2 = CH_3$
V: $R_1 = R_2 = H$



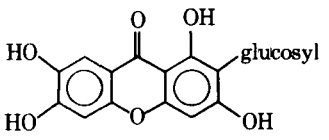
III: $R_1 = R_2 = R_3 = CH_3$
IV: $R_1 = R_2 = R_3 = H$



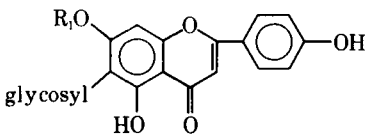
VI



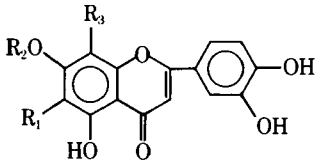
VII



VIII



IX: $R_1 = H$
XIII: $R_1 = CH_3$



X: $R_1 = H$, $R_2 = CH_3$, $R_3 =$ glycosyl
XI: $R_1 = R_2 = H$, $R_3 =$ glycosyl
XII: $R_1 =$ glycosyl, $R_2 = CH_3$, $R_3 = H$
XIV: $R_1 =$ glycosyl, $R_2 = R_3 = H$

In addition to these two xanthones, preparative layer chromatography furnished two minor xanthones from the middle zones. The identity of these two xanthones is currently being investigated.

Isolation of Xanthones from Alcoholic Extract—The ethanol extract of the defatted plant material was concentrated, and the concentrate was allowed to stand at room temperature overnight to detect the presence of mangiferin (8). Since no precipitate appeared, the extract was further concentrated to a syrupy liquid and was poured into aqueous acetic acid (4%, 200 ml). The mixture was kept at room temperature overnight. The precipitated pale-yellow solid was collected by filtration (Fraction D, xanthone *O*-glucosides) (2). The clarified acidic aqueous solution was extracted with ether (5 × 100 ml). The combined ether extracts were processed in the usual way and a dull-yellow solid (0.52 g) was obtained (Fraction E). The ether mother liquor (Fraction F) afforded two xanthones by column chromatography.

Separation of Xanthones from Fraction E—The solid (0.52 g) from Fraction E was extracted several times with hot chloroform to separate the chloroform-soluble fraction from the insoluble one.

1,3,7,8-Tetrahydroxyxanthone (IV)—The chloroform-insoluble solid (0.12 g) crystallized from methanol as yellow needles, mp 333–335°. The melting point, mixed melting point, R_f value, and UV and PMR spectra of the compound were identical with those of authentic 1,3,7,8-tetrahydroxyxanthone (3). The 3,7,8-trimethyl ether, prepared with ethereal diazomethane, crystallized from ethanol as yellow needles, mp and mixed mp (with decussatin) 148–149°.

1-Hydroxy-3,4,5,8-tetramethoxyxanthone (VII) and 1-Hydroxy-3,4,7,8-tetramethoxyxanthone (VI)—The methanol mother liquor, after separation of IV, was treated several times with ethereal diazomethane. The methylated product was subjected to preparative layer chromatography. The upper preparative layer zone afforded a further crop of decussatin (17 mg). The middle zone afforded VII (11 mg) as yellow needles, mp 186–188°. The melting point, mixed melting point, R_f value, and UV and mass spectra were identical with those of authentic, synthetic 1-hydroxy-3,4,5,8-tetramethoxyxanthone (9) (prepared from 1-hydroxy-3,5,8-trimethoxyxanthone by persulfate oxidation followed by methylation with diazomethane). The lower preparative layer zone afforded VI (15 mg) as yellow needles, mp 188–190°.

Separation of Xanthones from Fraction F—The ether mother liquor, after separation of Fraction E, was chromatographed over silica gel (20 × 1.8 cm). The column was eluted with benzene, benzene–chloroform (1:1), and chloroform, 2 liters each. The benzene and benzene–chloroform eluates afforded a further crop of xanthone I (92 mg).

1,3,5,8-Tetrahydroxyxanthone (V)—The chloroform eluates gave a brown solid (82 mg), which crystallized from ethanol as needles, mp 293–295° (M^+, 260, 100%). The trimethyl ether, prepared with ethereal diazomethane, was found to be identical with 1-hydroxy-3,5,8-trimethoxyxanthone (3) in all respects.

Persulfate Oxidation of 1-Hydroxy-3,5,8-trimethoxyxanthone—To a stirred solution of 1-hydroxy-3,5,8-trimethoxyxanthone (0.112 g) in aqueous potassium hydroxide (1.8 g in 2 ml of water) and pyridine (2 ml), an aqueous solution of potassium persulfate (0.23 g in 5 ml of water) was added over 3 hr. After another hour, the solution was neutralized to Congo red and the turbidity was removed by centrifugation. Further acidification of the centrifugate and treatment at 50° with sodium sulfite gave a precipitate which was extracted with ether.

The ether extract was worked up in the usual way. The residue (28 mg) was dissolved in methanol (5 ml) and treated with an excess of ethereal diazomethane. The methyl ether, 1-hydroxy-3,4,5,8-tetramethoxyxanthone, crystallized from ethanol as yellow needles, mp 186–188° [lit. (9) mp 187–188°]; *m/e* 332 (M^+, 100%). The UV absorption spectrum was identical to that reported in the literature (9).

The persulfate oxidation of decussatin and subsequent methylation of the product to 1-hydroxy-3,4,7,8-tetramethoxyxanthone were accomplished following similar procedures as described earlier.

RESULTS AND DISCUSSION

The entire plants were milled and extracted for polyoxygenated xanthones. The isolation and purification of the individual compounds (Scheme I) were accomplished by solvent extraction, column chromatography, preparative layer chromatography, and derivatization. The identity of the known compounds was established by UV, PMR, and mass spectra evidence and by direct comparison with reference samples (3, 8). The characterization of only the new xanthones is described here.

1-Hydroxy-3,4,7,8-tetramethoxyxanthone (VI)—The compound, $C_{17}H_{16}O_7$ (M^+, 332, 100%), mp 188–190°, is a monohydroxytetramethoxyxanthone in which the hydroxyl group is strongly chelated, since it remained unaffected with ethereal diazomethane but formed the permethyl ether with dimethyl sulfate and potassium carbonate in acetone. This finding was also supported by PMR data. The UV absorption spectrum of the compound is characteristic of a 1,3,4,7,8-pentaoxygenated xanthone (9).

The 60-MHz PMR spectrum of the compound, in deuterochloroform, showed one strongly chelated proton at δ 13.04 (C_1—OH), four methoxyl groups at δ 3.94–4.02, and three aromatic protons at δ 6.40 (1H, s, C_2—H), 7.05 (1H, d, J = 9 Hz, C_5—H), and 7.28 (1H, d, J = 9 Hz, C_6—H). In the mass spectrum of the xanthone, aside from the molecular ion peak, intense fragment ion peaks appeared at *m/e* 317 (35%), 302 (48), 289 (20), and 259 (10), associated with the loss of CH_3, CH_2O, C_2H_3O complex, and CH_2O + C_2H_3O groups, respectively, as supported by substantial abundances of metastable ions (3, 8, 10, 11).

On the basis of these observations and conclusions, the pentaox-

ygenated xanthone of *S. purpurascens* is assigned the 1-hydroxy-3,4,7,8-tetramethoxyxanthone structure (VI). Supporting evidence in favor of this conclusion was gained from its synthesis from decussatin. Persulfate oxidation of decussatin, followed by methylation with ethereal diazomethane, gave VI identical with the naturally occurring compound in all respects.

Partially Methylated Pentaoxygenated Xanthones Characterized as 1-Hydroxytetramethoxyxanthones (VI and VII)—TLC of the mixture of xanthones in Fraction E (Scheme I) showed the presence of two strongly polar components. These compounds could not be isolated directly by preparative layer chromatography. Methylation of the mixture with ethereal diazomethane, followed by preparative layer chromatography, afforded the two pentaoxygenated xanthones as homogeneous entities.

The identity of the two compounds was established by direct comparison with authentic synthetic 1-hydroxy-3,4,5,8-tetramethoxyxanthone (VII) and VI. Complete demethylation of the two monohydroxytetramethoxyxanthones with hydrobromic acid afforded the pentahydroxyxanthones, which were more polar than their naturally occurring counterparts. From this observation, it is reasonable to expect that the two pentaoxygenated xanthones (1,3,4,5,8- and 1,3,4,7,8-) are partially methylated. Because of the small quantities of these compounds, further identification was not possible.

Members of the genus *Swertia* are known to elaborate liberally the tetraoxygenated (1,3,5,8- and 1,3,7,8-) xanthones (3, 12); 1,3,4,5,8- and 1,3,4,7,8-pentaoxygenated xanthones are the first two pentaoxygenated xanthone patterns isolated from a member of this genus. The two oxygenation patterns were previously encountered only in the genus *Gentiana* (9). The resemblance in chemical characters of the two genera, *Swertia* and *Gentiana*, is striking. Thus, another significant similarity between the two genera was observed in the flavonoids cooccurring with the polyoxygenated xanthones.

The general pattern of flavonoid distribution in these two genera is the common one of glycoflavones (Table I). Exceptions were noted only in *G. septemfida* and *G. makinoi* (13), where glycoflavones were replaced by flavones. In *S. chirata, S. swertopsis,* and *G. lutea,* in addition to the glycoflavones, a glucoxanthone, mangiferin, was found to cooccur with glycoflavones. Mangiferin is a unique chemical character; both in its distribution and biogenesis, it seems to be more closely related to flavonoids than to xanthone derivatives (3, 8, 12, 14).

These observations and the assumption that the free flavones are vicariously represented by the glycoflavones in the mentioned *Swertia* and *Gentiana* species (Table I) give rise to a number of interesting speculations in plant biochemistry about the route by which synthesis of the flavones could be switched to glycoflavones; the reason for the sparse distribution of mangiferin in xanthone-bearing plants; and phytochemical relationship between taxa on the basis of oxygenation patterns of xanthones. Further studies are clearly necessary to draw any conclusion in this direction.

PHARMACOLOGY

Investigation of the pharmacological activity of the total xanthones (I–VII plus unidentified minor entities) of *S. purpurascens* was conducted on: *(a)* gross general behavior of albino mice and rats, *(b)* hexobarbital narcosis in mice, *(c)* reserpine-induced ptosis and sedation in mice, *(d)* amphetamine toxicity in aggregated mice, *(e)* subanalgesic doses of morphine in albino rats, *(f)* norepinephrine pressor response in pentobarbital-anesthetized dog, and *(g)* toxicity in albino rats.

Albino mice and rats, bred from the CDRI strains, and healthy mongrel dogs were used. The total xanthones were dissolved in 2% aqueous sodium carbonate solution and injected in a dose of 50 mg/kg ip (unless stated otherwise), keeping the volume of the injection at 1 ml/kg. The same volume of the vehicle was injected intraperitoneally to control animals. All experiments were conducted at ambient temperature of 24 ± 2°, according to previously described procedures (5, 6).

The total xanthones produced definite signs of CNS stimulation in albino mice and rats, as evidenced by the increased spontaneous motility, hyperactivity, fine tremors, and piloerection in their gross general behavior; significant potentiation (110% greater than the control) of hexobarbital narcosis; reversal of ptosis and sedation induced by reserpine; potentiation of amphetamine toxicity in aggregated mice (the mortality in the drug-treated group was 6/10 compared to 1/10 in the control group); and potentiation of analgesic effect of subanalgesic doses of morphine in albino rats (but had no analgesic effect *per se*). The total xanthones did not produce any significant potentiation (up to a dose of 100 mg/kg) of norepinephrine pressor response in dogs. The total xanthones were nontoxic up to a dose of 200 mg/kg ip in albino rats.

All methods used are accepted techniques for determining monoamine oxidase inhibiting activity of a compound *in vivo*. The central stimulant actions produced by the total xanthones of *S. purpurascens* are comparable to those of mangiferin (5, 6). Moreover, *in vitro* experiments with mangiferin definitely established that the central stimulant action of this glucoxanthone was mediated *via* monoamine oxidase inhibition. The details of this latter finding will be reported soon. Although the monoamine oxidase inhibiting activity of the total xanthones was not very pronounced, it had the advantage of being devoid of any adverse side effects, *e.g.*, high toxicity and potentiation of pressor effects of tyramine (and equivalents), commonly associated with well-known monoamine oxidase inhibitors.

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ACKNOWLEDGMENTS AND ADDRESSES

Received March 4, 1974, from the *Pharmaceutical Chemistry Research Laboratory, Department of Pharmaceutics, Banaras Hindu University, Varanasi-5, India.*

Accepted for publication July 17, 1974.

The authors are grateful to Professor G. B. Singh, Department of Chemistry, Banaras Hindu University, Varanasi-5, India, and Dr. Nitya Nand, Central Drug Research Institute, Lucknow, India, for obtaining the spectra, and to Mr. M. R. Uniyal for generous gifts of the plant materials. P. V. Sharma thanks the Banaras Hindu University for the award of a research fellowship.

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