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# PELTOGYNOIDS AND HOMOISOFLAVONOIDS FROM *CAESALPINIA PULCHERRIMA*

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**Key Word Index**—*Caesalpinia pulcherrima*; Leguminosae; peltogynoids; homoisoflavonoids.

**Abstract**—From the stem part of *Caesalpinia pulcherrima* Swartz (Leguminosae) two new peltogynoids, pulcherrimin and 6-methoxypulcherrimin and two homoisoflavonoids, the recently reported compound bonducellin and a new derivative 8-methoxy-bonducellin, were isolated. The structures of these constituents were deduced by consideration of their spectral data. Also isolated were the known compounds, 2,6-dimethoxybenzoquinone and 4′-methylisoliquiritigenin, which displayed cytotoxic activity.

## INTRODUCTION

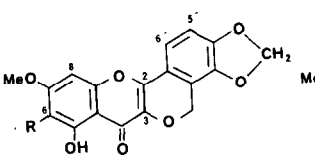
*Caesalpinia pulcherrima* Swartz is a large perennial shrub or small tree found throughout the tropics. It has been used as an ornamental and has such common names as 'Pride of Barbados', 'Peacock Flower' and 'Paradise Flower' [1]. According to folklore, the stem has been used primarily as an abortifacient and an emmenagogue [1]. Several genera of the Leguminosae are known to be sources of peltogynoids [2–5]. The new compounds of this class reported here are the first to possess a methylenedioxy group. Homoisoflavonoids, on the other hand, are substantially more restricted in their distribution, previously being reported only from genera in the Liliaceae [6–8], with one exception.*

This paper presents the isolation and characterization of two new peltogynoids, pulcherrimin (**1**) and 6-methoxypulcherrimin (**2**), two homoisoflavonoids, the recently reported bonducellin (**3**) and a new derivative 8-methoxybonducellin (**4**), and the known compounds 2,6-dimethoxybenzoquinone (**5**) and 4′-methylisoliquiritigenin (**6**).

## RESULTS AND DISCUSSION

A methanolic extract of the stem part of *C. pulcherrima* was diluted with water and consecutively partitioned with petroleum, chloroform and butanol. Column chromatography of the chloroform fraction resulted in the isolation of six compounds.

Pulcherrimin (**1**) was isolated as yellow needles, mp 231–232°, $M^+$ *m/z* 340 (100%) for $C_{18}H_{12}O_7$. Strong absorptions in the IR at 1650 (C=C) and 1630 $cm^{-1}$ (C=O) along with UV maxima at 377 and 272 nm indicated that the compound was in the flavone series with oxygenation at the 3-position [10]. A bathochromic shift of 48 nm in band I, induced by $AlCl_3$, unchanged on addition of HCl, indicated the presence of a 5-hydroxyl group. The $^1H$ NMR spectrum revealed the presence of two independent aromatic systems, each with two protons. The first consisted of a pair of doublets ($J$ = 8.2 Hz) at $\delta$ 7.36 and 6.86, corresponding to *ortho*-coupled C-6′ and C-5′ protons, respectively. The second aromatic system was comprised of a pair of doublets ($J$ = 2.3 Hz) at $\delta$ 6.45 and 6.35 corresponding to the *meta*-coupled C-8 and C-6 protons. Assignment of these four protons was based on data from related compounds [11]. A two-proton singlet at $\delta$ 6.07 suggested the presence of a methylenedioxy group, and was supported by IR absorption at 915 $cm^{-1}$ and confirmed by a positive Labat test. Two pyrano methylene protons were observed as a singlet at $\delta$ 5.24 and a single methoxy group was observed at $\delta$ 3.86. Finally, the 5-hydroxyl group was observed as a one proton singlet at $\delta$ 12.56. The methoxy group was assigned to the C-7 position based on the observation of a 5-hydroxyl group and *meta*-coupled protons in the A-ring. The methylenedioxy group of ring B could be assigned

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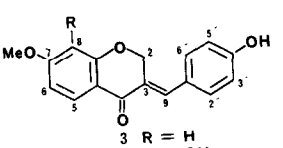


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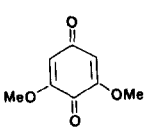


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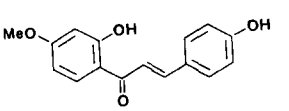


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*During the course of this work bonducellin (**3**) was isolated independently from the seed kernels of *C. bonducella* [9].

either to the 3',4'-position or to the 5',6'-position considering the *ortho*-coupled protons in this ring. Assignment to the 3',4'-position was made by comparison with related compounds [12], and is supported biogenetically. Therefore, pulcherrimin is represented by the structure 3,4-methylenedioxy-10-methoxy-8-hydroxy-6-oxo[2]benzopyrano[4,3-b]benzopyran (**1**).

6-Methoxypulcherrimin (**2**) was isolated as yellow needles, mp 270–271°, $M^+$ *m/z* 370 for $C_{19}H_{14}O_8$. The IR and UV spectra were very similar to those of pulcherrimin, with absorptions at 1655 (C=C) and 1640 $cm^{-1}$ (C=O) and maxima at 365 and 267 nm. A similar bathochromic shift induced by $AlCl_3$ was observed. The $^1H$ NMR spectrum of 6-methoxypulcherrimin differed from **1** in three aspects, the presence of two methoxy singlets at $\delta$ 3.96 and 3.92, the absence of the doublet at $\delta$ 6.35 and the simplification of the doublet at $\delta$ 6.45 to a singlet at $\delta$ 6.50. To assist in the location of the additional methoxy group, the $^1H$ NMR and mass spectra of the acetate derivative ($M^+$, *m/z* 412) were obtained. The single A-ring proton located at $\delta$ 6.50 in **2** was shifted upfield to $\delta$ 6.16 on conversion to the acetate. This shift of $\delta$ 0.34 upfield is characteristic of a proton *para* to a phenol on acetylation [13] suggesting that the A-ring proton is at C-8, and the second methoxy group at C-6. Additional evidence was obtained from the mass spectra of **2** and its acetate derivative in which substantial (70% or more) fragment ions were observed for the loss of 15 amu. This is characteristic of 6-methoxy- rather than 8-methoxy-flavonoid derivatives [14, 15]. 6-Methoxypulcherrimin is therefore 3,4-methylenedioxy-9,10-dimethoxy-8-hydroxy-7-oxo[2]benzopyrano[4,3-b]benzopyran (**2**).

Bonducellin (**3**) was isolated as yellow needles, mp 208°, $M^+$ *m/z* 282 for $C_{17}H_{14}O_4$. The IR spectrum showed strong absorptions at 1655 (C=C), 1615 (C=O) and 840 $cm^{-1}$ (*para* substituted benzene ring), and the UV spectrum showed maxima at 358 and 318 nm. The NaOAc-induced bathochromic shift in band I of 27 nm indicated the presence of a free hydroxyl group at position C-7 of an isoflavone. Examination of the $^1H$ NMR spectrum, in acetone-$d_6$, revealed the presence of three protons in the A-ring. A doublet centered at $\delta$ 7.83 was *ortho* coupled ($J$ = 8.6 Hz) to a one proton doublet of doublets centered at $\delta$ 6.60 ($J$ = 8.6, 2.2 Hz), which itself was *meta* coupled to a one proton doublet ($J$ = 2.2 Hz) at $\delta$ 6.38. These signals correspond to the C-5, C-6 and C-8 protons respectively. A perturbed AA'XX' system with two protons centered at $\delta$ 7.40 and two at $\delta$ 7.03 were assigned to the C-2',6' and C-3',5' protons, respectively. Centred at $\delta$ 7.70 was a one proton triplet ($J$ = 1.8 Hz) coupled to a two proton doublet ($J$ = 1.8 Hz) at $\delta$ 5.39. These signals were assigned to the C-9 and C-2 protons, respectively. The position of the C-9 proton at $\delta$ 7.70 is indicative of a *trans* double bond at this position [16]. The methoxy signal of $\delta$ 3.87 was assigned to the C-4' position, and is supported by the mass spectral fragment at *m/z* 146. These data are in agreement with the data reported in the literature [9]. Bonducellin is therefore represented by the structure 7-hydroxy-3-(4'-methoxybenzyl)-chroman-4-one (**3**).

8-Methoxybonducellin (**4**) was isolated as a yellow gum, $M^+$ *m/z* 312 for $C_{18}H_{16}O_5$. The IR and UV spectra were very similar to those of bonducellin, with absorptions at 1650 (C=C), 1610 (C=O) and 840 $cm^{-1}$ (*para* substituted benzene ring), and maxima at 358 and 310 nm. Bathochromic shifts induced by sodium methoxide and sodium acetate were observed. The $^1H$ NMR spectrum in acetone-$d_6$, exhibited only very slight chemical shift changes in the C-2 and C-9 protons, but did show the presence of methoxy groups at $\delta$ 3.88 and 3.83. In the A-ring, the doublet for the C-8 proton had disappeared, and the doublet of doublets for the C-6 proton had been reduced in complexity to a doublet ($J$ = 8.8 Hz) centered at $\delta$ 6.65. The C-5 proton signal was shifted slightly upfield to $\delta$ 7.61, but remained a doublet ($J$ = 8.8 Hz) *ortho*-coupled to the C-6 proton. 8-Methoxybonducellin is represented by the structure 7-hydroxy-8-methoxy-3-(4'-methoxybenzyl)-chroman-4-one (**4**).

## EXPERIMENTAL

*General.* Mps were determined using a Kofler hot-stage instrument and are uncorrected. Proton NMR spectra were recorded at 60 MHz on a Varian model T-60A instrument, equipped with a Nicolet model TT-7 Fourier Transform attachment. TMS was used as an internal standard and chemical shifts are reported on the $\delta$ scale. Low-resolution MS were obtained with a Varian MAT 112S double-focusing spectrometer operating at 70 eV.

*Plant material.* The plant material was collected in Sri Lanka in May, 1978, and identified as *Caesalpinia pulcherrima* Swartz. Herbarium specimens documenting this collection are deposited in the John G. Searle Herbarium of the Field Museum of Natural History, Chicago, IL, the Kew Herbarium, London, England and the Conservatoire et Jardin Botanique, Geneva, Switzerland.

*Extraction and fractionation.* Air dried and ground stem of *Caesalpinia pulcherrima* (32.65 kg) was extracted with MeOH. Concn of the extract *in vacuo* afforded a residue weighing 1.88 kg. The residue was dissolved in MeOH–$H_2O$ (1:2)(A) and successively partitioned between petrol (b.p. 60–80°) (B), $CHCl_3$ (C) and BuOH (D) to afford residues weighing A 1.17 kg, B 269 g, C 210 g and D 131 g.

*Chromatographic separation of the $CHCl_3$ fraction.* A portion of the $CHCl_3$ fraction (C) (180 g) was chromatographed on a column (A) of silica gel (5 kg) packed in petrol–$CHCl_3$ (17:3). A total of 114 fractions (1 l. each) were collected as the solvent was progressively changed to increasingly polar mixtures of petrol–$CHCl_3$, $CHCl_3$ and $CHCl_3$–MeOH. Fractions 42–53 (8.1 g) obtained from the above column (A) by elution with $CHCl_3$–2% MeOH were dissolved in $CHCl_3$–10% MeOH and allowed to stand at room temp. A yellow ppt. (200 mg) was recovered and rechromatographed on a column (B) of silica gel (40 g) and eluted with $CHCl_3$–1% EtOAc. A total of 38 fractions (20 ml each) were collected. The mother liquor from fractions 42–53 (7.9 g) of column (A) was rechromatographed on a column (C) of silica gel (250 g) and eluted with progressively increasing polar mixtures of $CHCl_3$ and EtOAc. A total of 217 fractions (20 ml each) were collected.

*Isolation of pulcherrimin* (**1**). Fractions 1–7 (23.5 mg) of column (B) and fractions 19–32 (400 mg) of column (C) afforded, after recrystallization from a mixture of $CHCl_3$ and MeOH, 18.2 mg and 31.8 mg of pulcherrimin (**1**), respectively, as yellow needles exhibiting the following physical and spectral properties; mp 231–232°; UV $\lambda_{max}^{EtOH}$ nm (log $\varepsilon$): 377 (3.92), 272 (4.32), (EtOH–$AlCl_3$) 425 (3.96), 369 (3.90), 285 (4.23), (EtOH–$AlCl_3$–HCl) 423 (3.90), 363 (3.93), 285 (4.20), (EtOH–NaOAc) 377 (3.98), 269 (4.31), (NaOAc–$H_3BO_3$) 377 (4.05), 270 (4.32), (EtOH–NaOMe) 405 (3.87), 298 (4.31), 266 (4.34); IR $\nu_{max}^{KBr}$ $cm^{-1}$: 3090, 2920, 1650, 1630, 1588, 1488, 1455, 1440, 1370, 1242, 1197, 1143, 1034, 988, 915, 867, 830, 800, 690; $^1H$ NMR ($CDCl_3$): $\delta$ 3.87 (3H, *s*, OMe), 5.24 (2H, *s*, pyrano $CH_2$),

6.07 (2H, *s*, $-OCH_2O-$), 6.35 (1H, *d*, $J = 8.4$ Hz, 6-H), 6.45 (1H, *d*, $J = 2.3$ Hz, 8-H), 6.86 (1H, *d*, $J = 8.2$ Hz, 5'-H), 7.36 (1H, *d*, $J = 8.4$ Hz, 6'-H), 12.6 (1H, *s*, exchanged with $D_2O$, 5-OH); MS *m/z*: 340 ($M^+$, 100%), 339 (15), 312 (17), 287 (45), 283 (3), 269 (4), 255 (7), 254 (2), 239 (5), 183 (3), 171 (3), 170 (4), 156 (18).

*Isolation of* 6-*methoxypulcherrimin* (**2**). Fractions 8–17 (26.1 mg) of column (B) and the second ppt. harvested from fractions 44–65 (250 mg) of column (C) yielded, after recrystallization from a mixture of $CHCl_3$ and MeOH, 21.5 mg and 23.5 mg of 6-methoxypulcherrimin (**2**), respectively, as yellow needles exhibiting the following physical and spectral properties: mp 270–271°; UV $\lambda_{max}^{EtOH}$ nm (log $\varepsilon$): 365 (3.68), 267 (3.69), (EtOH–$AlCl_3$) 427 (3.64), 382 (3.77), 280 (3.77), (EtOH–$AlCl_3$–HCl) 425 (3.59), 380 (3.75), 279 (3.74), (EtOH–NaOAc) 365 (3.73), 265 (3.75), (EtOH–NaOAc–$H_3BO_3$) 365 (3.81), 265 (3.76), (EtOH–NaOMe) 347 (3.61), 298 (3.64), 265 (3.61); IR $\nu_{max}^{KBr}$ $cm^{-1}$: 3090, 2920, 1655, 1640, 1592, 1460, 1438, 1368, 1358, 1275, 1236, 1195, 1171, 1102, 1080, 1038, 985, 970, 918, 828, 785; $^1H$ NMR ($CDCl_3$): $\delta$ 3.96 (3H, *s*, OMe), 3.92 (3H, *s*, OMe), 5.24 (2H, *s*, pyrano $CH_2$), 6.07 (2H, *s*, $-OCH_2O-$), 6.50 (1H, *s*, 8-H), 6.86 (1H, *d*, $J = 8.2$ Hz, 5'-H), 7.34 (1H, *d*, $J = 8.2$ Hz, 6'-H), 12.56 (1H, *s*, exchanged with $D_2O$, 5-OH); MS *m/z*, 370 ($M^+$, 100%), 369 (14), 356 (13), 355 (70), 354 (3), 353 (6), 352 (3), 342 (6), 341 (23), 340 (6), 339 (5), 328 (5), 327 (26), 256 (26), 185 (11), 163 (18), 162 (12).

*Isolation of bonducellin* (**3**). Fractions 18–26 (133.8 mg) of column (B), fractions 33–43 (1.2 g) of column (C) and the first ppt. harvested from fractions 44–56 (250 mg) of column (C) afforded, after recrystallization from a mixture of $CHCl_3$ and MeOH, 125.7 mg, 200 mg and 35 mg of bonducellin (**3**), respectively, as yellow needles. Bonducellin (**3**) exhibited the following physical and spectral properties; mp 208°; UV $\lambda_{max}^{EtOH}$ nm (log $\varepsilon$): 358 (4.21), 318 (4.16), (EtOH–$AlCl_3$) 358 (4.36), 318 (4.28), (EtOH–$AlCl_3$–HCl) 358 (4.36), 318 (4.28), (EtOH–NaOAc) 385 (4.22), 315 (4.14), (EtOH–NaOAc–$H_3BO_3$) 358 (4.43), 318 (4.36), (EtOH–NaOMe) 394 (4.23), 312 (3.95), 270 (3.69); IR $\nu_{max}^{KBr}$ $cm^{-1}$: 3240, 2970, 1655, 1615, 1602, 1573, 1510, 1476, 1330, 1308, 1291, 1259, 1234, 1177, 1155, 1102, 1028, 840; $^1H$ NMR (acetone-$d_6$): $\delta$ 3.31 (1H, *br s*, exchanged with $D_2O$, 7-OH), 3.87 (3H, *s*, OMe), 5.39 (2H, *d*, $J = 1.8$ Hz, 2-H), 6.38 (1H, *d*, $J = 2.2$ Hz, 8-H), 6.60 (1H, *dd*, $J = 2.2, 8.7$ Hz, 6-H), 7.03 (1H, 2H, *d*, $J = 8.9$ Hz, 3',5'-H), 7.40 (2H, *d*, $J = 8.9$ Hz, 2',6'-H), 7.70 (1H, *t*, $J = 1.8$ Hz, 9-H), 7.83 (1H, *d*, $J = 8.5$ Hz, 5-H); MS *m/z*; 282 ($M^+$, 100%), 281 (53), 267 (17), 253 (12), 239 (10), 211 (5), 165 (7), 150 (18), 147 (12), 146 (53), 145 (25), 137 (94), 131 (43), 127 (12), 115 (16), 108 (16), 103 (64), 102 (19), 77 (45), 51 (28).

*Isolation of* 8-*methoxybonducellin* (**4**). Prep. TLC of 20 mg of the mother liquor of fractions 44–56 of column (C) on silica gel $PF_{254}$ (20 × 20 × 0.2 cm) plates eluting with $CHCl_3$–EtOAc (3:1) yielded 8-methoxybonducellin (**4**, 3 mg) as a yellow gum exhibitng the following physical and spectral properties: UV $\lambda_{max}^{EtOH}$ nm (log $\varepsilon$): 358 (4.20), 328 (4.20), (EtOH–$AlCl_3$), 358 (4.20), 328 (4.19), (EtOH–$AlCl_3$–HCl) 358 (4.20), 328 (4.19), (EtOH–NaOAc) 378 (4.23), 328 (4.23), (EtOH–NaOAc–$H_3BO_3$) 358 (4.20), 328 (4.17), (EtOH–NaOMe) 400 (4.32), 310 (4.04), 271 (3.96); IR $\nu_{max}^{KBr}$ $cm^{-1}$: 3240, 2900, 1650, 1610, 1600, 1290, 1175, 840; $^1H$ NMR (acetone-$d_6$): $\delta$ 3.31 (1H, *br s*, exchanged with $D_2O$, 7-OH), 3.83 (3H, *s*, OMe), 3.88 (3H, *s*, OMe), 5.47 (2H, *d*, $J = 1.8$ Hz, 2-H), 6.65 (1H, *d*, $J = 8.8$ Hz, 6-H), 7.05 (2H, *d*, $J = 8.9$ Hz, 3',5'-H), 7.44 (2H, *d*, $J = 8.9$ Hz, 2',6'-H), 7.61 (1H, *d*, $J = 8.8$ Hz, 5-H) 7.72 (1H, *t*, $J = 1.8$ Hz, 9-H); MS *m/z*, 312 ($M^+$, 80%), 297 (7), 284 (11), 282 (17), 167 (56), 166 (13), 152 (8), 147 (17), 146 (100), 145 (15), 138 (34), 137 (27), 131 (25), 126 (9), 123 (15), 121 (35), 103 (35), 102 (11), 95 (16), 77 (29), 51 (16).

*Isolation and identification of* 2,6-*dimethoxybenzoquinone* (**5**). Fractions 54–62 (4.24 g) obtained from column (A) by elution with $CHCl_3$–MeOH (9:1) was rechromatographed on a column (D) of silica gel (140 g) and eluted with progressively increasing polar mixtures of $CHCl_3$ and EtOAc, collecting a total of 48 fractions (100 ml each). Fractions 6–7 (29 mg) eluted with $CHCl_3$–EtOAc (9:1) yielded 2,6-dimethoxybenzoquinone (**5**, 2.0 mg) after recrystallization from a mixture of $CHCl_3$ and MeOH. 2,6-Dimethoxybenzoquinone (**5**) was identified by comparison of its mp, UV, IR, $^1H$ NMR and MS with lit. values [17, 18], and by co-TLC with an authentic sample.

*Isolation and identification of* 4'-*methylisoliquiritigenin* (**6**). Fractions 69–73 (11.92 g) obtained from column (A) by elution with $CHCl_3$–MeOH (9:1) were rechromatographed on a column (E) of silica gel (400 g) and eluted with progressively increasing polar mixtures of $CHCl_3$, EtOAc and MeOH, collecting a total of 314 fractions (29 ml each). Fractions 61–139 (350 mg) eluted with $CHCl_3$–EtOAc (3:1) yielded the chalcone **6** (240 mg) after recrystallization from a mixture of $CHCl_3$ and MeOH. Compound **6** was identified by comparison of its mp, UV, IR, $^1H$ NMR and MS with lit. values [19].

*Biological activity*. Both compounds **5** and **6** were found to be cytotoxic in the KB test system *in vitro*, displaying an $ED_{50}$ of 2.8 $\mu$g/ml and 3.2 $\mu$g/ml, respectively [20].

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