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The incidence of crassulacean acid metabolism in Orchidaceae derived from carbon isotope ratios: a checklist of the flora of Panama and Costa Rica

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Leaf carbon stable isotopic composition data for 1002 orchid species representing 61% of the total number of orchid species described for Panama and Costa Rica were obtained from herbarium specimens to survey the occurrence of crassulacean acid metabolism (CAM). Carbon isotopic composition of leaf material showed a bimodal distribution with modes at –28‰, indicating C_3 photosynthesis, and at –15‰, indicating pronounced CAM photosynthesis. Strong CAM was present in 9.5% of species and in 31 of 162 genera studied. Twelve of these genera were not previously known to contain species exhibiting CAM. A checklist of orchids of Panama and Costa Rica with their $\delta^{13}C$ values and an updated list of all known orchid genera that possess species with the ability to perform CAM are presented.

ADDITIONAL KEYWORDS: carbon isotopes – Central America – epiphytes – herbarium – orchids – photosynthetic pathway.

INTRODUCTION

Crassulacean acid metabolism (CAM) is one of three photosynthetic pathways found in vascular plants for the assimilation of atmospheric CO_2. In contrast to C_3 and C_4 plants, CAM plants can perform substantial net CO_2 uptake from the atmosphere at night, reducing the amount of water lost per unit of carbon assimilated (i.e. greater water-use efficiency) (Winter & Smith, 1996; Cushman, 2001; Winter, Aranda & Holtum, 2005). CAM species are widely distributed throughout semi-arid tropical and subtropical environments, including epiphytic habitats in the humid tropics. Thus far, CAM has been reported for 343 genera in 34 families (Holtum *et al*., 2007) and approximately 7% of all vascular plant species are estimated to exhibit CAM (Smith & Winter, 1996; Holtum *et al*., 2007). Improving this estimate requires detailed work in species-rich families with large expected numbers of CAM species, such as Orchidaceae (Chase *et al*., 2003).

Several studies indicate that CAM photosynthesis may be widespread among tropical epiphytic orchids (Winter *et al*., 1983; Earnshaw *et al*., 1987; Silvera, Santiago & Winter, 2005; Silvera *et al*., 2009). Winter & Smith (1996) anticipated that 50% of tropical epiphytic orchids might perform CAM. Indeed, a survey of over 200 tropical orchid species showed strong or weak CAM in approximately 100 species (Silvera *et al*., 2005). In the current study, we targeted the rich orchid flora of Panama and Costa Rica, the 1640 species of which are well described by Dressler (1993). Carbon isotopic composition ($\delta^{13}C$) of bulk leaf tissue was used to determine the photosynthetic pathway in 1002 of these species, thus allowing us to identify species exhibiting strong CAM. This method takes advantage of differences in $\delta^{13}C$ of CAM and C_3 species, because $\delta^{13}C$ values of leaf carbon reflect the proportion of CO_2 gained by day via C_3 photosynthesis

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and by night via the CAM pathway (Ehleringer & Osmond, 1989; Winter & Holtum, 2002; Winter *et al*., 2005). However, because several species that have a C_3-type $\delta^{13}C$ value can also perform low level CAM activity (i.e. weak CAM), using only stable isotopic measurements to determine photosynthetic pathways can underestimate the number of species capable of performing CAM (Pierce, Winter & Griffiths, 2002; Silvera *et al*., 2005; Winter, Garcia & Holtum, 2008; Winter & Holtum, 2002). Analyses that combine nocturnal acidification measurements and diel gas-exchange patterns with isotopic composition are often employed to categorize further whether species are C_3, weak CAM or strong CAM (Pierce *et al*., 2002; Silvera *et al*., 2005). In this study, we used stable isotope measurements as a rapid screening method to categorize species as either predominantly C_3 or strong CAM, based on whether $\delta^{13}C$ values ranged from –33 to –22.1‰, which is typical of C_3 photosynthesis, or from –22 to –12‰, which is typical for strong CAM plants (Ehleringer & Osmond, 1989). The aims of this study were to update the number of orchid species performing CAM, provide a framework for further studies and provide a checklist of orchid genera in which the presence of CAM has been reported.

MATERIAL AND METHODS

Site description

Panama and Costa Rica are tropical, Central American countries located between 7° and 11°N and 77° to 85°W and form the narrowest part of the Mesoamerican Isthmus, thus serving as a land bridge between North and South America, and therefore fostering a rich mixture of plant and animal life that has migrated between the continents. This region contains all of the tropical life zones described by Holdridge (1967), with climatic ranges of mean annual precipitation of approximately 1140–5500 mm and mean annual temperature of 14–28 °C. Much of the regional climatic variation is caused by an elevation range from sea level to 3820 m, which results in an orographic distribution of precipitation. This diversity of habitats, therefore, covers the complete range of conditions in which tropical orchids are known to occur (Dressler, 1993), including native, urban, agricultural and disturbed habitats.

Carbon isotope analysis

Small fragments (2–5 mg) of leaf tissue were collected from 27 live species and herbarium specimens of 975 orchid species encompassing 162 genera at five herbaria: the Missouri Botanical Gardens Herbarium (MO), the Marie Selby Botanical Gardens Herbarium (SEL), the University of Florida Herbarium (FLAS), the University of Panama Herbarium (PMA) and the Smithsonian Tropical Research Institute Herbarium (SCZ). This sampling includes 61% of the orchid flora of Panama and Costa Rica described by Dressler (1993). Orchid nomenclature followed a combination of Dressler (1993) and the World Checklist of Monocotyledons (Royal Botanic Gardens, Kew) nomenclatural database and associated authority files (http://apps.kew.org/wcsp/home.do). Leaf samples were analysed for carbon stable isotopic composition ($\delta^{13}C$) at the Center for Stable Isotope Biogeochemistry, University of California Berkeley, using a continuous flow isotope ratio mass spectrometer (Finnigan-MAT Delta Plus XT). Ratios of $^{13}C/^{12}C$ were calculated relative to the Pee Dee belemnite standard (*Belemnitella americana*) using the relationship:

$$\delta^{13}C(‰) = [(^{13}C/^{12}C \text{ sample})/(^{13}C/^{12}C \text{ standard}) - 1] \times 1000.$$

Long-term external precision for $\delta^{13}C$ analyses is ± 0.22‰ when compared with standards. Based on the differential enzyme-mediated discrimination patterns against $^{13}CO_2$ during photosynthetic carbon assimilation, CAM and C_3 species have different whole leaf $\delta^{13}C$ values, such that values observed for C_3 plants range from –33 to –22.1‰, whereas $\delta^{13}C$ values characteristic of CAM plants range from –22 to –12‰ (Osmond *et al*., 1973; Ehleringer & Osmond, 1989; Pierce *et al*., 2002; Santiago *et al*., 2005; Silvera *et al*., 2005).

Because the $\delta^{13}C$ values of samples can be influenced by leaf development, and because non-photosynthetic tissues in C_3 species tend to be enriched in ^{13}C compared with leaves (Cernusak *et al*., 2009), only mature leaves were sampled and non-photosynthetic tissues were avoided. Similarly, specimens collected from the field were preferred over those grown in greenhouses or artificial conditions, to avoid the effects of variable $\delta^{13}C$ of source CO_2 in closed environments. Variation in $\delta^{13}C$ values from herbarium specimens of two or three individuals of the same species measured in 80 orchid species showed a standard deviation from ± 0.01 to 3.2 for both C_3 and strong CAM species (K. Silvera, unpubl. data). Variation within leaves of the sample species can also occur, but these differences are small relative to $\delta^{13}C$ variation between C_3 and strong CAM leaf tissue. For example, a recent study of the variation in $\delta^{13}C$ values of multiple leaves from individual tropical trees collected at different times of the year showed standard deviation of ± 0.1 to 0.5 in C_3 species (Holtum & Winter, 2005), and a study of the variation in $\delta^{13}C$ values of mature tissue of plants cultivated

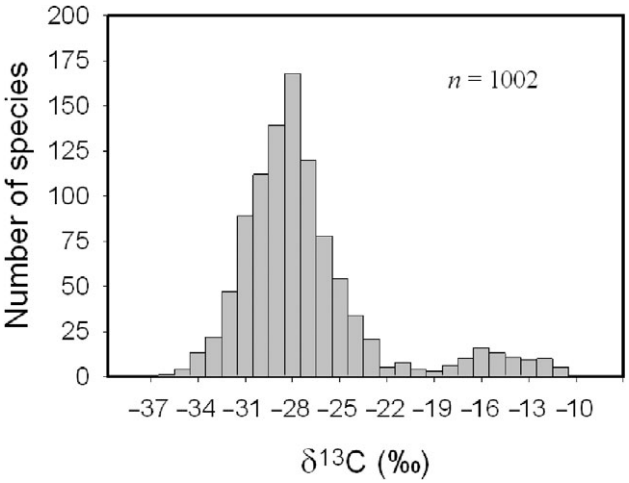

Figure 1. Frequency of leaf $\delta^{13}C$ values for 1002 Panamanian and Costa Rican orchid species. Each bar represents a 1‰ range of $\delta^{13}C$ values. Samples were collected at the Marie Selby Botanical Gardens Herbarium (SEL), the Missouri Botanical Gardens Herbarium (MO), the University of Florida Herbarium (FLAS), the University of Panama Herbarium (PMA) and Smithsonian Tropical Research Institute Herbarium (SCZ).

side-by-side showed standard deviation values of ± 0.1 to 0.3 in CAM species (Winter *et al*., 2005).

We also performed a literature survey to update a previous list (Smith & Winter, 1996) of the total number of orchid genera worldwide in which the presence of CAM has been reported.

RESULTS

Variation of bulk leaf $\delta^{13}C$ values of orchids from Panama and Costa Rica ranged from –36.5 to –11.4‰, with an average of –27.6‰. The frequency distribution of isotopic values among study species showed a bimodal distribution, with the majority of species at values *c*. –28‰ typical of C_3 photosynthesis, and a second mode at –15‰, typical of strong CAM photosynthesis (Fig. 1). Out of 1002 species, 907 (90.5%) belong to the C_3 photosynthesis cluster and 95 (9.5%) were strong CAM species based on $\delta^{13}C$ measurements.

Table 1 and Appendix S1 (available online) include detailed voucher information and $\delta^{13}C$ values of all species studied. Strong CAM was present in 31 of 162 (19%) genera surveyed in this study. All species surveyed within the genera *Barkeria* Knowles & Westc., *Brassavola* Adans., *Campylocentrum* Benth., *Cattleya* Lindl., *Caularthron* Raf., *Comparettia* Poepp. & Endl., *Encyclia* Hook., *Guarianthe* Dressler & W.E.Higgins, *Ionopsis* Kunth, *Laelia* Pers., *Leochilus* Knowles & Westc., *Macroclinium* Barb.Rodr. ex Pfltz., *Myrmecophila* Rolfe, *Notylia* Lindl., *Oeceoclades* Lindl., *Ornithocephalus* Hook., *Plectrophora* H.Focke, *Rodriguezia* Ruiz & Pav., *Trichocentrum* Poepp. & Endl.and *Trizeuxis* Lindl. showed strong CAM. In addition, strong CAM was present in at least one species of *Acianthera* Scheidw., *Camaridium* Lindl., *Elleanthus* C.Presl, *Epidendrum* L., *Heterotaxis* Lindl., *Lockhartia* Hook., *Myoxanthus* Poepp. & Endl., *Oncidium* Sw., *Pleurothallis* R.Br., Rossioglossum (Schltr.) Garay & G.C.Kenn. and *Vanilla* Mill.

The large neotropical genus *Epidendrum* with approximately 1200 species worldwide was the most sampled in this study (143 species) and contained the largest proportion of CAM species (24; Table 1). The second most sampled genus, *Maxillaria* (110 species) with approximately 550 species worldwide, did not show any strong CAM species. Only two of 49 species of another large genus, *Pleurothallis*, which is currently under extensive revision, showed strong CAM. *Scaphyglottis* Poepp. & Endl. and *Sobralia* Ruiz & Pav., the fourth and fifth most sampled genera in this study, did not show any strong CAM species. All species previously assigned to the genera *Cohniella* Pfitzer and *Lophiaris* Raf., which were previously part of *Oncidium*, but have now been merged into the genus *Trichocentrum* (Williams *et al*., 2001), showed strong CAM.

Our checklist represents the first known report of the presence of CAM in 12 genera, bringing the total number of orchid genera known to contain CAM species to 90, considering previous literature reports and recent nomenclatural changes (Table 2).

DISCUSSION

Our finding that the distribution of C_3 and CAM photosynthetic pathways among orchids of Panama and Costa Rica shows a bimodal distribution along the complete isotopic range of study species is consistent with previous isotope-based screening campaigns of CAM taxa (Neales & Hew, 1975; Griffiths & Smith, 1983; Winter *et al*., 1983; Pierce *et al*., 2002; Crayn, Winter & Smith, 2004; Holtum *et al*., 2004; Silvera *et al*., 2005). That the majority of species are clustered around the C_3 isotopic range, with a smaller cluster around the CAM isotopic range and only a few species with intermediate $\delta^{13}C$ values (Fig. 1), is indicative of specialization in carbon assimilation pathways and probable biochemical and/or anatomical limitations associated with these isotopic ranges (Silvera *et al*., 2005). The bimodal distribution suggests that strong CAM or C_3 photosynthesis is favoured over intermediate metabolisms. Species rely on one pathway or the other, probably based on available ecological niches. Strong CAM is present in 9.5% of the study species, but the bimodal distribution fails

Table 1. Leaf carbon isotopic values (‰) and voucher information for 1002 orchid species from Panama and Costa Rica, including current taxonomic name and herbarium accession number

SUBFAMILY			
Tribe			
Species	Herbarium	Accession no.	$\delta^{13}C$ (‰)
SUBFAMILY VANILLOIDEAE			
Tribe Pogonieae			
Cleistes rosea Lindl.	MO	3042034	–28.8
Tribe Vanilleae			
Vanilla inodora Schiede	FLAS	205833	–29
**Vanilla planifolia* Jacks. ex Andrews	MO	1986318	–15.3
**Vanilla pompona* Schiede	MO	2481055	–15.9
**Vanilla trigonocarpa* Hoehne	FLAS	168044	–21.7
SUBFAMILY CYPRIPEDIOIDEAE			
Phragmipedium humboldtii (Warsz. ex Rchb.f.) J.T.Atwood & Dressler	MO	4272449	–26.6
Phragmipedium longifolium (Rchb.f. & Warsz.) Rolfe	FLAS	202849	–31.7
Phragmipedium warszewiczianum Schltr.	FLAS	149690	–26.8
Selenipedium chica Rchb.f. & Warsz.	SEL	45447	–31.8
SUBFAMILY ORCHIDOIDEAE			
Tribe Cranichideae			
Subtribe Goodyerinae			
Aspidogyne roseoalba (Dressler) Ormerod	SEL	67280	–34.6
Aspidogyne tuerkheimii (Schltr.) Garay	MO	2601082	–34.8
Erythrodes sp.	SEL	66795	–28.3
Goodyera erosa (Ames & G.Schweinf.) Ames	SEL	68616	–30.7
Goodyera fimbrilabia Ormerod	SEL	68461	–33.8
Goodyera micrantha Schltr.	SEL	66719	–36.5
Kreodanthus sarcochilus E.A.Christ. sp. nov. ined.	MO	2908235	–31.5
Microchilus calophylla (Rchb.f.) Ormerod	PMA	44668	–34.9
Microchilus nigrescens (Schltr.) Ormerod	SEL	68600	–35.6
Microchilus tridax (Rchb.f.) Ormerod	FLAS	205754	–34.4
Microchilus vesicifer (Rchb.f.) Ormerod	SEL	64831	–35.3
Microchilus whitefoordiae Ormerod	SEL	56638	–33.5
Platythelys epidendroides ined.	MO	3224443	–33.1
Platythelys maculata (Hook.) Garay	MO	2241194	–34.2
Platythelys querceticola (Lindl.) Garay	SEL	71119	–34.4
Subtribe Spiranthinae			
Beloglottis costaricence (Rchb.f.) Schltr.	SEL	57543	–33.7
Coccineorchis bracteosa (Ames & C.Schweinf.) Garay	SEL	75623	–32.3
Coccineorchis cernua (Lindl.) Garay	SEL	61512	–31
Coccineorchis cristata Szlach., Ruttk. & Mytnik	MO	3479970	–29.9
Coccineorchis navarrensis (Ames) Garay	MO	3311782	–31.1
Coccineorchis standleyi (Ames) Garay	MO	2606908	–30.9
Coccineorchis warszewicziana Szlach., Rutk. & Mytnik	MO	3659052	–26.8
Cyclopogon elatus (Sw.) Schltr.	MO	4272041	–32.8
Cyclopogon miradorensis Schltr.	MO	2938757	–31.5
Cyclopogon plantagineus Schltr.	MO	3502879	–30
Eurystyles standleyi Ames	FLAS	185783	–31.8
Pelexia funkiana (A.Rich. & Galeotti) Schltr.	MO	2928674	–34.1
Pelexia smithii (Rchb.f.) Garay	SEL	Live 1991-131	–27.1
Sacoila lanceolata (Aubl.) Garay	MO	2012389	–28.1
Sarcoglottis sceptrodes (Rchb.f.) Schltr.	SEL	60172	–30.9

Table 1. *Continued*

SUBFAMILY			
Tribe			
Species	Herbarium	Accession no.	$\delta^{13}C$ (‰)
Sarcoglottis sceptrodes (Rchb.f.) Schltr.	SEL	Live 2003-0136A	–28.1
Sarcoglottis smithii (Rchb.f.) Schltr.	SEL	69065	–29.8
Sarcoglottis woodsonii (L.O.Williams) Garay	MO	1172202	–27
Stenorrhynchos speciosum (Jacq.) Rich. ex Spreng.	MO	3032040	–32.6
Subtribe Cranichidinae			
Baskervilla colombiana Garay	MO	4273395	–34.5
Cranichis reticulata Rchb.f.	MO	3271517	–31.7
Cranichis saccata Ames	SEL	56635	–30.3
Cranichis wageneri Rchb.f.	SEL	68643	–29.6
Gomphichis adnata (Ridl.) Schltr.	FLAS	202846	–30.4
Gomphichis hetaerioides Schltr.	SEL	52169	–30.6
Ponthieva brenesii Schltr.	MO	2628583	–30.1
Ponthieva ephippium Rchb.f.	MO	1171744	–30.1
Ponthieva formosa Schltr.	MO	5345769	–27.9
Ponthieva inaudita Rchb.f.	MO	5587748	–31.7
Ponthieva racemosa (Walter) C.Mohr	SEL	61047	–29.2
Ponthieva tuerckheimii Schltr.	FLAS	180035	–34.2
Prescottia stachyodes (Sw.) Lindl.	SEL	61437	–30.5
Pseudocentrum hoffmannii Rchb.f.	MO	3878256	–28.3
Pterichis galeata Lindl.	SEL	65456	–28.3
Pterichis habenarioides (F.Lehm. & Kraenzl.) Schltr.	SEL	1585	–27.9
Solenocentrum costaricense Schltr.	MO	2481258	–31.9
Tribe Orchideae			
Subtribe Orchidinae			
Habenaria alata Hook.	MO	2353007	–29
Habenaria avicula Schltr.	MO	2323571	–34.1
Habenaria clypeata Lindl.	SCZ	2195	–28.6
Habenaria dentifera C.Schweinf.	MO	5052280	–30.5
Habenaria distans Griseb.	SEL	68284	–35.2
Habenaria eustachya Rchb.f.	MO	2061019	–31.7
Habenaria lactiflora A.Rich. & Galeotti	MO	3532267	–30.1
Habenaria lankesteri Ames	SEL	66890	–30.6
Habenaria mediocris Dressler	MO	5345789	–27.9
Habenaria monorrhiza (Sw.) Rchb.f.	SEL	71389	–33.1
Habenaria petalodes Lindl.	MO	1785355	–28.9
Habenaria repens Nutt.	SEL	68294	–31.1
Habenaria rodeiensis Barb.Rodr.	MO	2937360	–30.7
Habenaria strictissima Rchb.f.	PMA	17532	–33.9
Habenaria trifida Kunth	SEL	14012	–27.1
Habenaria wercklei Schltr.	MO	2323000	–28.4
SUBFAMILY EPIDENDROIDEAE			
Tribe Neottieae			
Palmorchis powellii (Ames) C.Schweinf. & Correll	MO	5345774	–34.5
Palmorchis silvicola L.O.Williams	PMA	17796	–32.3
Palmorchis trilobulata L.O.Williams	FLAS	205794	–35.1
Palmorchis trinotata Dressler	SEL	15670	–33.6
Tribe Sobralieae			
Elleanthus aurantiacus (Lindl.) Rchb.f.	FLAS	No number	–27.5
Elleanthus bradeorum Schltr.	MO	4302326	–25.6

Table 1. *Continued*

SUBFAMILY			
Tribe			
Species	Herbarium	Accession no.	$\delta^{13}C$ (‰)
**Elleanthus capitatus* (Poepp. & Endl.) Rchb.f.	MO	5325352	–21.7
Elleanthus caricoides Nash	FLAS	178179	–29.7
Elleanthus cynarocephalus (Rchb.f.) Rchb.f.	MO	5345761	–31.4
Elleanthus fractiflexus Schltr.	MO	5345780	–31.2
Elleanthus glaucophyllus Schltr.	FLAS	188734	–27.5
Elleanthus graminifolius (Barb.Rodr.) Lojtnant	SCZ	2127	–26.4
Elleanthus hymenophorus (Rchb.f.) Rchb.f.	FLAS	205748	–30.1
Elleanthus jimenezii (Schltr.) C.Schweinf.	MO	5345770	–28.3
Elleanthus lancifolius C.Presl	FLAS	178181	–30.5
Elleanthus laxus Schltr.	MO	4964566	–26.2
Elleanthus lentii Barringer	MO	2481114	–29.5
Elleanthus longibracteatus (Lindl. ex Griseb.) Fawc.	MO	5161467	–31.2
Elleanthus muscicola Schltr.	MO	5345752	–31.9
Elleanthus poiformis Schltr.	MO	5345800	–29.8
Elleanthus robustus (Rchb.f.) Rchb.f.	MO	5605116	–27.3
Elleanthus scopula Schltr.	MO	5324713	–27.5
Elleanthus stolonifer Barringer	FLAS	No number	–29.5
Elleanthus tillandsioides Barringer	PMA	46870	–29.5
Elleanthus tonduzii Schltr.	FLAS	178176	–25.5
Elleanthus tricallosus Ames & C.Schweinf.	FLAS	No number	–30.5
Elleanthus wercklei Schltr.	PMA	32657	–29.8
Sobralia albolutea Dressler	FLAS	205812	–24.8
Sobralia allenii L.O.Williams	SEL	1714	–26.1
Sobralia amabilis (Rchb.f.) L.O.Williams	MO	4304243	–28.6
Sobralia atropubescens Ames & C.Schweinf.	SEL	71279	–24.6
Sobralia bletiae Rchb.f.	MO	2072598	–27
Sobralia callosa L.O.Williams	MO	3594106	–29.2
Sobralia candida (Poepp. & Endl.) Rchb.f.	MO	5345810	–30.6
Sobralia carazoi Lank. & Ames	SEL	66695	–27.2
Sobralia chrysostoma Dressler	MO	5170269	–29.3
Sobralia corazoi Lank. & Ames	MO	4649925	–29.2
Sobralia decora Bateman	MO	1939722	–31.7
Sobralia doremiliae Dressler	MO	4952726	–26.5
Sobralia fragrans Lindl.	MO	4952724	–25.2
Sobralia helleri A.D.Hawkes	FLAS	No number	–28.7
Sobralia kerryae Dressler	MO	5345793	–29
Sobralia labiata Warsz. Rchb.f.	SEL	10885	–28.1
Sobralia lancea Garay	FLAS	178187	–28.9
Sobralia leucoxantha Rchb.f.	MO	5079696	–31.3
Sobralia lindleyana Rchb.f.	MO	4270746	–28.4
Sobralia luteola Rolfe	FLAS	205819	–31
Sobralia macra Schltr.	FLAS	178188	–28.1
Sobralia macrophylla Rchb.f.	MO	2057755	–28.6
Sobralia mucronata Ames & C.Schweinf.	FLAS	205822	–26.1
Sobralia nutans Dressler	MO	4270747	–25.9
Sobralia powellii Schltr.	FLAS	205823	–30.8
Sobralia quinata Dressler	SEL	66722	–30
Sobralia undatocarinata C.Schweinf.	MO	4951499	–31.6
Sobralia valida Rolfe	MO	5345758	–29.1

Table 1. *Continued*

SUBFAMILY			
Tribe			
Species	Herbarium	Accession no.	$\delta^{13}C$ (‰)
Sobralia warszewiczii Rchb.f.	FLAS	205814	–26.1
Sobralia wilsoniana Rolfe	MO	1980717	–26.2
Tribe Tropidieae			
Corymborkis flava (Sw.) Kuntze	FLAS	205741	–32
Corymborkis forcipigera (Rchb.f. & Warsz.) L.O.Williams	SEL	75632	–33.6
Tribe Triphoreae			
Monophyllorchis microstyloides (Rchb.f.) Garay	SEL	68889	–30.7
Psilochilus macrophyllus (Lindl.) Ames	MO	3608753	–28.7
Tribe Calypsoeae			
Govenia ciliilabia Ames & C.Schweinf.	MO	3500547	–26.9
Govenia quadriplicata Rchb.f.	MO	4242855	–31.1
Govenia utriculata (Sw.) Lindl.	MO	1943608	–27.5
Subtribe Chysinae			
Chysis violacea Dressler	SEL	Live 2007-0058A	–25.7
Subtribe Ponerinae			
Isochilus carnosiflorus Lindl.	SEL	71569	–28.8
Isochilus linearis (Jacq.) R.Br.	SEL	68053	–27.9
Isochilus major Cham. & Schltdl.	SEL	68059	–27.4
Subtribe Bletiinae			
Bletia campanulata La Llave & Lex.	MO	2614940	–23
Bletia purpurea (Lam.) DC.	SEL	79845	–28.9
Subtribe Pleurothallidinae			
**Acianthera decipiens* (Ames & C.Schweinf.) Pridgeon & M.W.Chase	SEL	13493	–15.1
Acianthera glumacea (Lindl.) Pridgeon & M.W.Chase	MO	4273643	–30
Acianthera johnsonii (Ames) Pridgeon & M.W.Chase	SEL	13488	–29.1
**Acianthera lepidota* (L.O.Williams) Pridgeon & M.W.Chase	SEL	15513	–14.6
**Acianthera lojae* (Schltr.) Luer	SEL	15714	–17.1
**Acianthera oscitans* (Ames) Pridgeon & M.W.Chase	SEL	13524	–17.6
Acianthera pantasmi (Rchb.f.) Pridgeon & M.W.Chase	SEL	57542	–23.9
**Acianthera pubescens* (Lindl.) Pridgeon & M.W.Chase	MO	4658643	–16.5
**Acianthera sicaria* (Lindl.) Pridgeon & M.W.Chase	MO	2662908	–20.4
**Acianthera verecunda* (Schltr.) Pridgeon & M.W.Chase	MO	2049780	–11.7
Anathallis barbulata (Lindl.) Pridgeon & M.W.Chase	MO	2060988	–28.9
Anathallis cuspidata (Luer) Pridgeon & M.W.Chase	MO	3326498	–28.6
Anathallis dolichopus (Schltr.) Pridgeon & M.W.Chase	MO	3498723	–33
Anathallis lewisiae (Ames) Solano & Soto Arenas	SEL	3040	–27.6
Anathallis polygonoides (Griseb.) Pridgeon & M.W.Chase	SEL	14030	–25.2
Anathallis sclerophylla (Lindl.) Pridgeon & M.W.Chase	SEL	55642	–28.4
Barbosella circinata Luer	SCZ	13291	–30
Barbosella dolichoriza Schltr.	MO	5463884	–25.8
Barbosella geminata Luer	SEL	67906	–31.3
Barbosella orbicularis Luer	FLAS	No number	–30
Barbosella prorepens (Rchb.f.) Schltr.	MO	5463907	–26.9
Brachionidium calypso Luer	MO	3872241	–31.2
Brachionidium cruzae L.O.Williams	MO	3220275	–30.7
Brachionidium dressleri Luer	MO	2481263	–32.2

Table 1. *Continued*

SUBFAMILY			
Tribe			
Species	Herbarium	Accession no.	$\delta^{13}C$ (‰)
Brachionidium filamentosum Luer & Hirtz	MO	2928662	–32.1
Brachionidium folsomii Dressler	MO	4026942	–32
Brachionidium haberi Luer	MO	3708380	–31.5
Brachionidium polypodium Luer	MO	3493256	–30.9
Brachionidium pusillum Ames & C.Schweinf.	MO	4390476	–31.8
Diodonopsis erinacea (Rchb.f.) Pridgeon & M.W.Chase	MO	3311771	–31
Diodonopsis pygmaea (Kraenzl.) Pridgeon & M.W.Chase	SEL	66552	–33.5
Dracula astuta (Rchb.f.) Luer	SEL	38195	–28.5
Dracula erythrochaete (Rchb.f.) Luer	MO	3152269	–31.7
Dracula gaskelliana (Rchb.f.) Luer	SEL	51038	–24.8
Dresslerella hispida (L.O.Williams) Luer	PMA	4176	–29.3
Dresslerella pertusa (Dressler) Luer	MO	2107591	–29.3
Dryadella butcheri Luer	MO	2136946	–29.6
Dryadella dressleri Luer	SEL	52038	–28.1
Dryadella gnoma (Luer) Luer	SEL	52054	–31.7
Dryadella guatemalensis (Schltr.) Luer	SEL	77210	–29.6
Dryadella odontostele Luer	MO	3515525	–31.4
Echinosepala lappiformis (A.H.Heller & L.O.Williams) Pridgeon & M.W.Chase	SEL	13221	–27.1
Echinosepala sempergemmata (Luer) Pridgeon & M.W.Chase	MO	2623825	–28.3
Echinosepala uncinata (Fawc.) Pridgeon & M.W.Chase	MO	3659007	–31.3
Lepanthes antilocapra Luer & Dressler	PMA	54852	–27.7
Lepanthes blepharistes Rchb.f.	SEL	38136	–30.3
Lepanthes brunnescens Luer	MO	3716824	–31.9
Lepanthes chameleon Ames	SEL	50565	–27.8
Lepanthes ciliisepala Schltr.	SEL	50547	–31.5
Lepanthes coeloglossa Luer	SEL	66774	–31.1
Lepanthes crossota Luer	MO	3432797	–29.2
Lepanthes eciliata Schltr.	SEL	66485	–34.8
Lepanthes elata Rchb.f.	PMA	26726	–29.4
Lepanthes eximia Ames	SEL	50533	–31.6
Lepanthes grandiflora Ames & C.Schweinf.	PMA	54864	–26.5
Lepanthes helleri A.D.Hawkes	SEL	65298	–26.8
Lepanthes horichii Luer	SEL	66481	–32.4
Lepanthes horrida Rchb.f.	SEL	38152	–23.2
Lepanthes jimenezii Schltr.	SEL	66396	–29.3
Lepanthes lindleyana Oerst. & Rchb.f.	SEL	66398	–27.5
Lepanthes maxonii (Schltr.)	PMA	54866	–33
Lepanthes monteverdensis Luer & R.Escobar	SEL	65261	–28.4
Lepanthes myiophora Luer	SEL	65257	–30.9
Lepanthes mystax Luer & R.Escobar	SEL	51984	–28.3
Lepanthes psyche Luer	SEL	52006	–25.7
Lepanthes pygmaea Luer	SEL	54355	–28.9
Lepanthes tipulifera Rchb.f.	SEL	50519	–29.1
Lepanthes turialvae Rchb.f.	SEL	38208	–24.4
Lepanthes wendlandii Rchb.f.	SCZ	12438	–31.4
Masdevallia attenuata Rchb.f.	SEL	51987	–29.3
Masdevallia calura Rchb.f.	SEL	28499	–32.4
Masdevallia chasei Luer	SEL	67910	–25.6
Masdevallia chontalensis Rchb.f.	MO	2480972	–30.3

Table 1. *Continued*

SUBFAMILY			
Tribe			
Species	Herbarium	Accession no.	$\delta^{13}C$ (‰)
Masdevallia collina L.O.Williams	SEL	13514	–25.4
Masdevallia cupularis Rchb.f.	SEL	28543	–26.8
Masdevallia lata Rchb.f.	SEL	58981	–30.8
Masdevallia laucheana J.Fraser	SEL	18301	–26.9
Masdevallia livingstoneana Roezl & Rchb.f.	MO	1982949	–30.6
Masdevallia molossoides Kraenzl.	SEL	71080	–29.6
Masdevallia morenoi Luer	SEL	24765	–26.9
Masdevallia nidifica Rchb.f.	MO	3201961	–30.5
Masdevallia olmosii Koniger & Sijm	PMA	54880	–31.1
Masdevallia picturata Rchb.f.	SEL	38156	–28.2
Masdevallia rafaeliana Luer	SEL	28521	–31.3
Masdevallia reichenbachiana Endrés ex Rchb.f.	SEL	18321	–27.3
Masdevallia rolfeana Kraenzl.	SEL	80335	–28
Masdevallia scabrilinguis Luer	SEL	51989	–28.3
Masdevallia schizopetala Kraenzl.	SEL	68839	–31
Masdevallia striatella Rchb.f.	SEL	67909	–30.8
Masdevallia tonduzii Woolward	SEL	41162	–24.6
Masdevallia tubuliflora Ames	SEL	28381	–32.8
**Myoxanthus colothrix* (Luer) Luer	MO	2242082	–15.8
Myoxanthus exasperatus (Lindl.) Luer	SEL	13454	–27.5
Myoxanthus hirsuticaulis (Ames & C.Schweinf.) Luer	MO	2199648	–29.2
Myoxanthus octomeriae (Schltr.) Luer	MO	1208672	–23.5
Myoxanthus scandens (Ames) Luer	PMA	4273	–27.6
Myoxanthus speciosus (Luer) Luer	MO	2107232	–27.6
Myoxanthus trachyclamys (Schltr.) Luer	SEL	93277	–28.3
Octomeria costaricensis Schltr.	MO	2241388	–31.6
Octomeria graminifolia (L.) R.Br.	MO	3586975	–26.1
Phloeophila pelecaniceps (Luer) Pridgeon & M.W.Chase	MO	2136945	–24.2
Phloeophila peperomioides (Ames) Garay	MO	2601868	–27.2
Platystele brenneri Luer	MO	5463927	–29.3
Platystele calymma Luer	MO	5463931	–30
Platystele caudatisepala (C.Schweinf.) Garay	MO	5463937	–32.5
Platystele compacta (Ames) Ames	MO	2481019	–28.8
Platystele jungermannioides (Schltr.) Garay	SEL	66549	–29.6
Platystele lancilabris (Rchb.f.) Schltr.	SEL	73330	–32.1
Platystele microtatantha (Schltr.) Garay	SEL	66545	–30.3
Platystele ovalifolia (H.Focke) Garay & Dunst.	MO	2937293	–33.3
Platystele oxyglossa (Schltr.) Garay	MO	2623594	–31
Platystele pedicellaris (Schltr.) Garay	SEL	66548	–29.2
Platystele stenostachya (Rchb.f.) Garay	SEL	79273	–29.3
Platystele taylorii Luer	MO	5464003	–29.9
Pleurothallis allenii L.O.Williams	MO	3311759	–28.3
Pleurothallis annectens Luer	SEL	Live 1977-1746A	–30.8
Pleurothallis archicolonae Luer	SEL	51977	–30
Pleurothallis bivalvis Lindl.	MO	2937577	–30.1
Pleurothallis bothros Luer	SEL	68904	–24.7
Pleurothallis cardiochila L.O.Williams	MO	2167250	–28.8
Pleurothallis cardiothallis Rchb.f.	SEL	68854	–29
Pleurothallis chloroleuca Lindl.	MO	4273588	–28
Pleurothallis colossus Kraenzl. ex Kerch	MO	3138467	–30.8

Table 1. *Continued*

SUBFAMILY			
Tribe			
Species	Herbarium	Accession no.	$\delta^{13}C$ (‰)
Pleurothallis coriacardia Rchb.f.	SEL	93279	–30.9
Pleurothallis crescentilabia Ames	SEL	70789	–28
Pleurothallis crocodiliceps Rchb.f.	MO	2606987	–26.5
Pleurothallis cucumeris Luer	SEL	29856	–29
Pleurothallis dentipetala Rolfe ex Ames	MO	4273633	–31.7
Pleurothallis discoidea Lindl.	MO	4273433	–26
Pleurothallis divaricans Schltr.	SEL	15633	–27.6
Pleurothallis dorotheae Luer	SEL	51094	–26.8
Pleurothallis dressleri Luer	MO	2205136	–29.2
**Pleurothallis ellipsophylla* L.O.Williams	MO	1227011	–12.2
Pleurothallis eumecocaulon Schltr.	MO	4658642	–28
Pleurothallis eumecocaulon Schltr.	MO	2740035	–28.6
Pleurothallis excavata Schltr.	MO	2060987	–28.2
Pleurothallis hemileuca Luer	MO	2941700	–25.1
Pleurothallis homalantha Schltr.	PMA	25398	–31.7
Pleurothallis isthmica Luer	MO	2167251	–29.4
Pleurothallis longipedicellata Ames & C.Schweinf.	MO	3432760	–32.7
Pleurothallis loranthophylla Rchb.f.	MO	2167252	–27.8
Pleurothallis luctuosa Rchb.f.	SEL	51082	–24.9
Pleurothallis mammillata Luer	SEL	18360	–27.8
**Pleurothallis nuda* (Klotzsch) Rchb.f.	SEL	Live 2002-0146A	–21.1
Pleurothallis oncoglossa Luer	SEL	28556	–26.4
Pleurothallis pallida Luer	MO	2787483	–30.5
Pleurothallis palliolata Ames	MO	3224437	–28.9
Pleurothallis peculiaris Luer	MO	2908220	–29.1
Pleurothallis phyllocardia Rchb.f.	MO	1934966	–23.4
Pleurothallis phyllocardioides Schltr.	MO	4274961	–29.5
Pleurothallis picta Hook	MO	4658641	–30
Pleurothallis pleurothalloides (Cogn.) Handro	MO	3772357	–32.3
Pleurothallis pruinosa Lindl.	MO	2999579	–27.2
Pleurothallis radula Luer	SEL	66569	–30.6
Pleurothallis rectipetala Ames & C.Schweinf.	MO	2937272	–29.4
Pleurothallis rhodoglossa Schltr.	MO	2937585	–29.7
Pleurothallis rowleei Ames	MO	4273624	–32.4
Pleurothallis rubella Luer	MO	4273626	–30.2
Pleurothallis ruscifolia (Jacq.) R.Br.	MO	4272349	–29
Pleurothallis sanchoi Ames	SEL	70961	–28
Pleurothallis titan Luer	MO	4273442	–26.3
Pleurothallis tonduzii Schltr.	SEL	70974	–30
Pleurothallis uncinata Fawc.	MO	4273417	–30
Pleurothallis volcanica Luer	MO	2937253	–31.6
Pleurothallopsis tubulosa Lindl.	SEL	66734	–30.9
Pleurothallopsis ujarensis (Rchb.f.) Lindl.	SEL	15411	–25.5
Restrepia muscifera (Lindl) Rchb.f. ex Lindl.	MO	2241438	–24.1
Restrepia trichoglossa F.Lehm. ex Sander	MO	3520961	–31.7
Restrepiella ophiocephala (Lindl.) Garay & Dunst.	SEL	Live 2002-132	–28.6
Scaphosepalum clavellatum Luer	MO	2481134	–28.1
Scaphosepalum microdactylum Rolfe	MO	2353021	–29.9
Scaphosepalum pittieri Schltr.	PMA	4498	–29
Specklinia acrisepala Ames & C.Schweinf.	MO	4273437	–28.6

Table 1. *Continued*

SUBFAMILY			
Tribe			
Species	Herbarium	Accession no.	$\delta^{13}C$ (‰)
Specklinia amparoana (Schltr.) Luer	MO	2928621	–27
Specklinia aristata (Hook.) Pridgeon & M.W.Chase	SEL	28484	–29.7
Specklinia barbae (Schltr.) Luer	SEL	16875	–31.2
Specklinia bicornis (Luer) Pridgeon & M.W.Chase	SEL	52031	–29.7
Specklinia brighamii (S.Watson) Pridgeon & M.W.Chase	MO	2937332	–31.7
Specklinia cactantha (Luer) Pridgeon & M.W.Chase	SEL	3005	–29.9
Specklinia calyptrostele (Schltr.) Pridgeon & M.W.Chase	MO	2060999	–29.8
Specklinia condylata (Luer) Pridgeon & M.W.Chase	SEL	52013	–30.8
Specklinia convallaria (Schltr.) Luer	SEL	13505	–27.4
Specklinia corniculata (Sw.) Steud.	MO	2928703	–28.7
Specklinia costaricensis (Rolfe) Pridgeon & M.W.Chase	MO	2249598	–27.1
Specklinia costaricensis (Rolfe) Pridgeon & M.W.Chase (as *Acostaea pleurothalloides* Schltr.)	MO	2896003	–29.8
Specklinia endotrachys (Rchb.f.) Pridgeon & M.W.Chase	MO	2635149	–27.8
Specklinia fimbriata Ames & C.Schweinf.	SEL	70908	–30.2
Specklinia fuegi (Rchb.f.) Solano & Soto Arenas	SEL	51089	–28.1
Specklinia fulgens (Rchb.f.) Pridgeon & M.W.Chase	SEL	66744	–31.7
Specklinia glandulosa (Ames) Pridgeon & M.W.Chase	MO	2937304	–29.7
Specklinia grobyi (Bateman ex Lindl.) F.Barros	MO	1941061	–27.4
Specklinia guanacastensis (Ames & C.Schweinf.) Pridgeon & M.W.Chase	SEL	56628	–30.7
Specklinia herpestes (Luer) Pridgeon & M.W.Chase	SEL	28483	–28
Specklinia lanceola (Sw.) Lindl.	SEL	31467	–28.8
Specklinia mirifica Pridgeon & M.W.Chase	MO	2338552	–31
Specklinia microphylla (A.Rich. & Galeotti) Pridgeon & M.W.Chase	MO	4273430	–31.2
Specklinia recula (Luer) Luer	SEL	3147	–28.6
Specklinia segregatifolia (Ames & C.Schweinf.) Solano & Soto Arenas	MO	2999583	–29.4
Specklinia simmleriana (Rendle) Luer	SEL	67698	–32.6
Specklinia strumosa (Ames) Pridgeon & M.W.Chase	SEL	71129	–29
Specklinia tribuloides (Sw.) Pridgeon & M.W.Chase	SCZ	13265	–27.7
Specklinia tripterantha (Rchb.f.) Luer	MO	2914918	–25.7
Specklinia turrialbae (Luer) Luer	SEL	66885	–32.4
Specklinia uniflora (Lindl.) Pridgeon & M.W.Chase	SEL	24898	–28.1
Stelis alajuelensis Pridgeon & M.W.Chase	SEL	51171	–28.5
Stelis alta Pridgeon & M.W.Chase	SEL	51085	–29.1
Stelis aprica Lindl.	SEL	57538	–27.8
Stelis argentata Lindl.	MO	5751821	–30.4
Stelis atrorubens L.O.Williams	MO	4274955	–32.5
Stelis brunnea (Dressler) Pridgeon & M.W.Chase	MO	3106368	–27.3
Stelis butcheri Luer	SEL	13718	–28.2
Stelis canae (Ames) Pridgeon & M.W.Chase	MO	2482054	–32.9
Stelis carnosilabia (A.H.Heller & A.D.Hawkes) Pridgeon & M.W.Chase	SEL	68353	–26.7
Stelis carpinterae (Schltr.) Pridgeon & M.W.Chase	MO	3138486	–29.5
Stelis ciliaris Lindl.	MO	2302031	–30.9
Stelis cresentiicola Schltr.	MO	2057880	–31.4
Stelis cylindrata Pridgeon & M.W.Chase	MO	3432761	–29.2
Stelis deregularis Barb.Rodr.	SEL	73592	–26.9
Stelis despectans Schltr.	MO	2623608	–29.7
Stelis dracontea (Luer) Pridgeon & M.W.Chase	SEL	66575	–28
Stelis fortunae (Luer & Dressler) Pridgeon & M.W.Chase	MO	2937588	–31.8

Table 1. *Continued*

SUBFAMILY			
Tribe			
Species	Herbarium	Accession no.	$\delta^{13}C$ (‰)
Stelis gelida (Lindl.) Pridgeon & M.W.Chase	SEL	57539	–30.8
Stelis gigantea Pridgeon & M.W.Chase	MO	3432755	–25.7
Stelis gracilis Ames	SEL	38792	–28.2
Stelis guttata (Luer) Pridgeon & M.W.Chase	SEL	2000	–29.2
Stelis hymenantha Schltr.	MO	2241176	–27.2
Stelis immersa (Linden & Rchb.f.) Pridgeon & M.W.Chase	SEL	71244	–26.5
Stelis imraei (Lindl.) Pridgeon & M.W.Chase	MO	4658647	–29.5
Stelis janetiae (Luer) Pridgeon & M.W.Chase	SEL	51084	–29.5
Stelis jimenezii Schltr.	SEL	41265	–31.8
Stelis lankesteri Ames	MO	2999589	–26.9
Stelis macrophylla Kunth	SEL	10721	–24.8
Stelis maculata Pridgeon & M.W.Chase	SEL	3029	–29.1
Stelis maxima Lindl.	MO	3595552	–31.8
Stelis megachlamys (Schltr.) Pupulin	MO	4069555	–25.6
Stelis microchila Schltr.	MO	4274940	–28.8
Stelis montana L.O.Williams	MO	2144451	–31.4
Stelis morganii Dodson & Garay	SEL	28514	–28
Stelis multirostris (Rchb.f.) Pridgeon & M.W.Chase	SEL	70902	–26
Stelis mystax (Luer) Pridgeon & M.W.Chase	MO	2983915	–32.5
Stelis papillifera (Rolfe) Pridgeon & M.W.Chase	SEL	71236	–31.8
Stelis pardipes Rchb.f.	MO	5751820	–29.4
Stelis parvula Lindl.	SEL	68156	–30.7
Stelis pompalis (Ames) Pridgeon & M.W.Chase	MO	5309890	–27.8
Stelis powellii Schltr.	MO	2923133	–30.6
Stelis purpurascens A.Rich. & Galeotti	SEL	16788	–26.7
Stelis purpurea (Ruiz & Pav.) Willd.	SEL	56497	–30.5
Stelis segoviensis (Rchb.f.) Pridgeon & M.W.Chase	SEL	33107	–27.2
Stelis semperflorens Luer	SEL	38813	–30.5
Stelis simplex (Ames & C.Schweinf.) Pridgeon & M.W.Chase	SEL	71233	–27.4
Stelis spathulata Poepp. & Endl.	MO	3593455	–31.9
Stelis storkii Ames	MO	4274953	–29
Stelis superbiens Lindl.	MO	2941697	–29.4
Stelis thymochila (Luer) Pridgeon & M.W.Chase	MO	3432763	–30.3
Stelis transversalis Ames	SEL	38814	–31.1
Stelis umbelliformis Hespenh. & Dressler	SEL	35739	–29.7
Stelis vestita Ames	MO	2481246	–27.1
Stelis williamsii Ames	SEL	11171	–27.4
Trichosalpinx arbuscula (Lindl.) Luer	MO	2637405	–27.3
Trichosalpinx blaisdellii (S.Watson) Luer	SEL	54595	–29
Trichosalpinx carinilabia (Luer) Luer	MO	3432787	–28.4
Trichosalpinx cedralensis (Ames) Luer	MO	2149613	–27.5
Trichosalpinx ciliaris (Lindl.) Luer	SEL	18356	–28.5
Trichosalpinx dura (Lindl.) Luer	MO	3131353	–28.2
Trichosalpinx memor (Rchb.f.) Luer	MO	2926925	–23.8
Trichosalpinx orbicularis (Lindl.) Luer	MO	2635146	–25.7
Trichosalpinx pergrata (Ames) Luer	MO	2623595	–33.5
Trichosalpinx rotundata (C.Schweinf.) Dressler	MO	4593874	–27.2
Trichosalpinx tantilla (Luer) Luer	MO	2937349	–28.8
Trisetella dressleri (Luer) Luer	MO	2060985	–31
Trisetella triaristella (Rchb.f.) Luer	SEL	50944	–28.6

Table 1. *Continued*

SUBFAMILY			
Tribe			
Species	Herbarium	Accession no.	$\delta^{13}C$ (‰)
Trisetella triglochin (Rchb.f.) Luer	SEL	66543	–33.9
Zootrophion dayanum (Rchb.f.) Luer	SEL	Live 2002-0130A	–25.5
Zootrophion endresianum (Kraenzl.) Luer	SEL	29843	–29.5
Subtribe Laeliinae			
Acrorchis roseola Dressler	MO	3479948	–27.8
Arpophyllum giganteum Hartw. ex Lindl.	FLAS	205734	–25.1
**Barkeria lindleyana* Bateman ex Lindl.	SEL	68061	–18.3
**Brassavola nodosa* (L.) Lindl.	FLAS	205736	–14.2
**Cattleya dowiana* Bateman	SEL	12473	–12.7
**Caularthron bilamellatum* (Rchb.f.) R.E.Schult.	SCZ	2142	–14.3
Dimerandra emarginata (G.Mey) Hoehne	SEL	65609	–27.5
Dimerandra isthmii Schltr.	MO	2146310	–27
**Encyclia amanda* (Ames) Dressler	MO	5345792	–16.2
**Encyclia ceratistes* (Lindl.) Schltr.	SEL	68224	–15
**Encyclia cordigera* (Kunth) Dressler	MO	3398419	–15
**Encyclia gravida* (Lindl.) Schltr.	SCZ	2134	–16.5
**Encyclia stellata* (Lindl.) Schltr.	SEL	74287	–18.2
Epidendrum acrostigma Hágsater & García-Cruz	MO	5046291	–27.1
Epidendrum adnatum Ames & C.Schweinf.	SEL	56620	–31.3
Epidendrum alfaroi Ames & C.Schweinf.	SEL	65934	–28.8
Epidendrum allenii L.O.Williams	MO	3201936	–28.7
**Epidendrum amparoana* Schltr.	MO	2928619	–17
Epidendrum anceps Jacq.	SEL	Live 2004-0032A	–23.3
Epidendrum anoglossoides Ames & C.Schweinf.	SEL	53592	–28.9
Epidendrum anoglossum Schltr.	SEL	64569	–26.3
Epidendrum antonense Hágsater	MO	2940045	–29.2
Epidendrum barbae Rchb.f.	SEL	66926	–28.9
Epidendrum barbeyanum Kraenzl.	PMA	27026	–24.1
**Epidendrum baumannianum* Schltr.	MO	3273717	–17.9
Epidendrum bilobatum Ames	SEL	80007	–23.8
Epidendrum bisulcatum Ames	MO	2604919	–29.5
**Epidendrum cardiophorum* Schltr.	PMA	8578	–12.6
Epidendrum carpophorum Barb.Rodr.	MO	2903062	–28.6
Epidendrum centropetalum Rchb.f.	SEL	64014	–28.2
**Epidendrum chogoncolonchence* Hágsater & Dodson	SEL	Live 2006-62	–16.3
**Epidendrum ciliare* L.	MO	3877024	–12.4
Epidendrum cirrhochilum F.Lehm. & Kraenzl.	MO	2896001	–30.2
Epidendrum cocleense Ames, F.T.Hubb & C.Schweinf.	MO	5779467	–24
Epidendrum cordiforme C.Schweinf.	SEL	51207	–27.7
**Epidendrum coriifolium* Lindl.	FLAS	140579	–20.4
**Epidendrum coronatum* Ruiz & Pav.	MO	2782358	–18.7
Epidendrum corrifolium Lindl.	PMA	17936	–22.1
Epidendrum cresentiloba Ames	MO	3887635	–30.5
Epidendrum criniferum Rchb.f.	SEL	Live 1974-0030-054B	–27.4
Epidendrum cryptanthum L.O.Williams	SEL	61978	–31.8
Epidendrum dentilobum Ames	PMA	54879	–26.5
Epidendrum difforme Jacq.	PMA	26356	–25.9
Epidendrum eburneum Rchb.f.	MO	3492205	–26.5
Epidendrum ellipsophyllum L.O.Williams	MO	3289595	–34
Epidendrum endresii Rchb.f.	MO	4251244	–30.2

Table 1. *Continued*

SUBFAMILY			
Tribe			
Species	Herbarium	Accession no.	$\delta^{13}C$ (‰)
Epidendrum exasperatum Rchb.f.	MO	5781131	–29.2
Epidendrum exile Ames	MO	2937322	–28.2
Epidendrum firmum Rchb.f.	SEL	69032	–25.3
Epidendrum flexicaule Schltr.	SEL	66961	–33
Epidendrum flexuosissimum C.Schweinf.	MO	3271515	–28.6
Epidendrum folsomii Hágsater & E.Santiago	MO	2937618	–26.8
Epidendrum fortunae Hágsater & Dressler	MO	2928625	–30.4
Epidendrum fuscinun (Dressler) Hágsater	MO	3493362	–28.4
**Epidendrum* cf. *galeochilum* Hágsater & Dressler	MO	4302604	–21.5
Epidendrum gibbosum L.O.Williams	SEL	61540	–29.3
**Epidendrum glumibracteum* Rchb.f.	SEL	68265	–18.8
Epidendrum goniorhachis Schltr.	SEL	51179	–28.8
Epidendrum hunterianum Schltr.	MO	4302609	–24.8
**Epidendrum ibaguense* Kunth in F.W.H. von Humboldt, A.J.A.Bonpland & C.S.Kunth	PMA	19147	–15.6
**Epidendrum imatophyllum* Lindl.	SCZ	2171	–15.7
Epidendrum incomptum Rchb.f.	MO	5779473	–29.5
Epidendrum insolatum Barringer	PMA	26749	–26
Epidendrum insulanum Schltr.	SEL	16873	–23.8
Epidendrum intermixtum Ames & C.Schweinf.	SEL	56434	–27.4
Epidendrum isomerum Schltr.	FLAS	83823	–27.4
Epidendrum isthmii Schltr.	MO	3496953	–29.6
Epidendrum jefeallenii Hágsater & García-Cruz	MO	5779463	–28.8
Epidendrum jefestigma Hágsater & García-Cruz	MO	4302495	–27.2
Epidendrum lacustre Lindl.	MO	3431736	–27.8
Epidendrum lancilabium Schltr.	SEL	38433	–28.3
Epidendrum lankesteri Ames	SEL	66929	–32.2
Epidendrum laucheanum Bonhof ex Rolfe	SEL	64616	–30.2
Epidendrum lechleri Rchb.f.	SEL	66962	–27
**Epidendrum lockhartioides* Schltr.	MO	4305160	–17.4
Epidendrum longibracteatum Hágsater & García-Cruz	MO	5779481	–28.8
**Epidendrum macroclinium* Hook.	SEL	54601	–20.5
Epidendrum maduroi Hágsater & García-Cruz	MO	4304250	–29.2
Epidendrum magnibracteatum Ames	SEL	64833	–27.4
Epidendrum mantisreligiosae Hágsater	MO	2937236	–25.4
Epidendrum microdendron Rchb.f.	SEL	66951	–28.5
Epidendrum miserrimum Rchb.f.	MO	2937377	–30
Epidendrum mora-retanae Hágsater	SEL	Live 2003-0298A	–27
Epidendrum muscicola Schltr.	FLAS	185780	–28.4
Epidendrum myodes Rchb.f.	MO	5781126	–29.8
Epidendrum nocturnum Jacq.	MO	4298834	–24
Epidendrum notabile Schltr.	MO	3431746	–31.6
Epidendrum nutantirhachis Ames & C.Schweinf.	MO	5781122	–26
Epidendrum octomerioides Schltr.	SEL	57544	–25.8
Epidendrum odontochilum Hágsater	MO	4305124	–25.3
**Epidendrum oerstedii* Rchb.f.	MO	4336238	–16
Epidendrum oxyglossum Schltr.	MO	5779461	–25
Epidendrum pajitense C.Schweinf.	PMA	454	–25.4

Table 1. *Continued*

SUBFAMILY			
Tribe			
Species	Herbarium	Accession no.	$\delta^{13}C$ (‰)
Epidendrum pallens Rchb.f.	MO	2481241	–32.4
Epidendrum palmidium Hágsater	MO	3289619	–25.9
Epidendrum panamense Schltr.	MO	5779456	–33.4
Epidendrum paniculatum Ruiz & Pav.	FLAS	107426	–28.4
Epidendrum pansamalae Schltr.	SEL	17468	–30.8
Epidendrum paraguastigma Hágsater & García-Cruz	MO	4298846	–27.9
Epidendrum paranthicum Rchb.f.	SCZ	2155	–30.1
**Epidendrum parkinsonianum* Hook.	MO	2896587	–16.5
Epidendrum parviexasperatum Hágsater	SEL	70558	–28.8
Epidendrum paucifolium Schltr.	MO	3203974	–29.5
**Epidendrum peperomia* Rchb.f.	SEL	9709	–19.4
Epidendrum pergameneum (Rchb.f.)	MO	5779477	–25.6
Epidendrum phragmites A.H.Heller & L.O.Williams	FLAS	No number	–27.9
Epidendrum phyllocharis Rchb.f.	MO	2928742	–30.2
**Epidendrum physodes* Rchb.f.	SEL	19445	–16.6
Epidendrum piliferum Rchb.f.	MO	5779493	–30
Epidendrum plagiophyllum Hágsater	SEL	79970	–25.7
Epidendrum platystigma Rchb.f.	MO	4298832	–29.6
Epidendrum pleurothalloides Hágsater	MO	5781117	–29.2
Epidendrum polyanthum Lindl.	SEL	76135	–32
Epidendrum polychlamys Schltr.	PMA	54853	–27.7
Epidendrum powellii Schltr.	MO	3431747	–28.6
Epidendrum pseudoramosum Schltr.	SEL	66960	–30.2
Epidendrum pseudoschumannianum Fowlie	SEL	9175	–24.7
Epidendrum pseudo-wallisii Schltr.	MO	3131340	–30.5
Epidendrum pumila Rolfe	MO	2937253	–27.4
Epidendrum puteum Standl. & L.O.Williams	FLAS	83240	–31.1
**Epidendrum radicans* Pav. ex Lindl.	SEL	66697	–17
Epidendrum ramonianum Schltr.	SEL	68149	–28.2
Epidendrum ramosum Jacq.	MO	5779489	–25.6
Epidendrum repens Cogn.	SEL	56837	–28.3
Epidendrum rigidiflorum Schltr.	MO	5781118	–27
**Epidendrum rigidum* Jacq.	MO	5161584	–20.2
Epidendrum rugosum Ames	MO	5779484	–29.7
Epidendrum sanchoi Ames	SCZ	2185	–28.3
Epidendrum sancti-ramoni Kraenzl.	MO	2710890	–26.8
Epidendrum santaclarense Ames	MO	5779474	–27.9
**Epidendrum scalpelligerum* Rchb.f.	SEL	12315	–18.8
**Epidendrum schlecterianum* Ames	MO	3273716	–16.3
Epidendrum schumannianum Schltr.	MO	3131341	–30.4
**Epidendrum sculptum* Rchb.f.	MO	2937362	–16.8
Epidendrum selaginella Schltr.	MO	3138485	–28.9
**Epidendrum stamfordianum* Bateman	SCZ	2187	–16.3
Epidendrum stevensii Hágsater	SEL	51187	–27.1
Epidendrum stolidium Hágsater	MO	3111760	–28.3
Epidendrum storkii Ames	SEL	65543	–23.6
**Epidendrum strobiliferum* Rchb.f.	SEL	56811	–21.9
Epidendrum strobiloides Garay & Dunst.	SEL	Live 2003-0243A	–25
Epidendrum subnutans Ames & C.Schweinf.	MO	5779492	–30.5
Epidendrum summerhayesii Hágsater	MO	2937511	–27.1

Table 1. *Continued*

SUBFAMILY			
Tribe			
Species	Herbarium	Accession no.	$\delta^{13}C$ (‰)
Epidendrum suturatum Hágsater & Dressler	MO	2908228	–30.5
Epidendrum talamancanum (J.T.Atwood) Mora-Ret. & García Castro	MO	2623817	–28.4
Epidendrum tenuisulcata (Dressler) Hágsater	PMA	22869	–28.8
Epidendrum tetraceros Rchb.f.	MO	3857308	–29.2
Epidendrum thurstonorum Dodson & Hágsater	MO	3432783	–22.2
Epidendrum trachythece Schltr.	SEL	66932	–29.4
Epidendrum trialatum Hágsater	MO	5779466	–29.5
Epidendrum turialvae Rchb.f.	MO	5779468	–30.5
Epidendrum veraguasense Hágsater	MO	2928579	–30.4
Epidendrum veroscriptum Hágsater	SEL	57336	–28.9
Epidendrum vincentinum Lindl.	SEL	67057	–31
Epidendrum wallisii Rchb.f.	MO	5779488	–25.9
Epidendrum wercklei Schltr.	SEL	64859	–28.3
**Guarianthe patinii* (Cogn.) Dressler & W.E.Higgins	SEL	Live 1991-0251A	–18.8
**Guarianthe skinneri* (Bateman) Dressler & W.E.Higgins	MO	4964599	–16.6
Homalopetalum pumilio (Rchb.f.) Schltr.	MO	4904348	–26.2
Jacquiniella equitantifolia (Ames) Dressler	SEL	74233	–26.3
Jacquiniella globosa (Jacq.) Schltr.	FLAS	185785	–27.3
Jacquiniella pedunculata Dressler	MO	2061010	–27.7
Jacquiniella teretifolia (Sw.) Britton & P.Wilson	SEL	13948	–23.5
**Laelia rubescens* Lindl.	SEL	Live 1990-497	–16.6
**Myrmecophila tibicinis* (Bateman ex Lindl.) Rolfe	MO	4956371	–12.9
Nidema boothii (Lindl.) Schltr.	SEL	56408	–28.8
Prosthechea abbreviata (Schltr.) W.E.Higgins	FLAS	186628	–25
Prosthechea aemula (Lindl.) W.E.Higgins	SEL	39359	–27.2
Prosthechea brassavolae (Rchb.f.) W.E.Higgins	MO	3111765	–28.5
Prosthechea campylostalix (Rchb.f.) W.E.Higgins	MO	2481059	–28.7
Prosthechea chacaoensis (Rchb.f.) W.E.Higgins	FLAS	205798	–27.3
Prosthechea chimborazoensis (Schltr.) W.E.Higgins	MO	4304248	–26.6
Prosthechea cochleata (L.) W.E.Higgins	SEL	75613	–28.5
Prosthechea crassilabia (Poepp. & Endl.) Carnevali & I.Ramírez	FLAS	No number	–29.2
Prosthechea fragrans (Sw.) W.E.Higgins	SEL	74286	–27.7
Prosthechea ionocentra (Rchb.f.) W.E.Higgins	MO	2897374	–23.9
Prosthechea ionophlebia (Rchb.f.) W.E.Higgins	MO	3878255	–26.7
Prosthechea livida (Lindl.) W.E.Higgins	MO	3421921	–29.6
Prosthechea ochracea (Lindl.) W.E.Higgins	SEL	72340	–24.7
Prosthechea prismatocarpa (Rchb.f.) W.E.Higgins	MO	2007425	–24
Prosthechea pseudopygmaea (Finet) W.E.Higgins	SEL	51185	–26.7
Prosthechea pygmaea (Hook.) W.E.Higgins	MO	2938765	–31
Prosthechea racemifera (Dressler) W.E.Higgins	SEL	56835	–29.2
Prosthechea racemifera (Dressler) W.E.Higgins	MO	2584335	–29
Prosthechea sima (Dressler) W.E.Higgins	MO	2011426	–26.7
Prosthechea spondiada (Rchb.f.) W.E.Higgins	SEL	9989	–23
Prosthechea vagans (Ames) W.E.Higgins	SEL	73347	–24.8
Prosthechea vespa (Vell.) W.E.Higgins	MO	2066184	–28.6
Scaphyglottis acostaei (Schltr.) C.Schweinf.	FLAS	205802	–30.1
Scaphyglottis amparoana (Schltr.) Dressler	SEL	72167	–27.9
Scaphyglottis arctata (Dressler) B.R.Adams	MO	3311767	–27.3
Scaphyglottis behrii (Rchb.f.) Benth. & Hook.f. ex Hemsl.	MO	1986378	–28.4
Scaphyglottis bidentata (Lindl.) Dressler (*Hexisea bidentata* Lindl.)	SCZ	12459	–28.9

Table 1. *Continued*

SUBFAMILY			
Tribe			
Species	Herbarium	Accession no.	$\delta^{13}C$ (‰)
Scaphyglottis bifida (Rchb.f.) C.Schweinf.	SEL	72234	–28.4
Scaphyglottis bilineata (Rchb.f.) Schltr.	FLAS	187198	–33.3
Scaphyglottis boliviensis (Rolfe) B.R.Adams	FLAS	205803	–27.5
Scaphyglottis chlorantha B.R.Adams	MO	2480921	–28.5
Scaphyglottis clavata Dressler	MO	2199651	–28.7
Scaphyglottis corallorrhiza (Ames) Ames, F.T.Hubb. & C.Schweinf.	FLAS	187202	–28
Scaphyglottis coriacea (L.O.Williams) Dressler	MO	2166595	–30.1
Scaphyglottis crurigera (Bateman ex Lindl.) Ames & Correll	MO	3152084	–28.9
Scaphyglottis cuniculata (Schltr.) Dressler	MO	4904326	–25.1
Scaphyglottis densa (Schltr.) B.R.Adams	FLAS	205807	–29
Scaphyglottis fusiformis (Griseb.) R.E.Schult.	MO	2118428	–26.5
Scaphyglottis gigantea Dressler	MO	3772331	–24.9
Scaphyglottis imbricata (Lindl.) Dressler	SEL	61820	–27.3
Scaphyglottis jimenezii Schltr.	FLAS	187201	–28.5
Scaphyglottis laevilabium Ames	MO	5752973	–30.2
Scaphyglottis lindeniana (A.Rich. & Galeotti) L.O.Williams	FLAS	187203	–26.5
Scaphyglottis longicaulis S.Watson	MO	2107216	–29
Scaphyglottis mesocopis (Endrés & Rchb.f.) Benth. & Hook.f. ex Hemsl.	FLAS	205808	–30.3
Scaphyglottis micrantha (Lindl.) Ames & Correll	SEL	72179	–29.5
Scaphyglottis minutiflora Ames & Correll	FLAS	205809	–31.3
Scaphyglottis modesta (Rchb.f.) Schltr.	FLAS	187204	–29.7
Scaphyglottis pachybulbon (Schltr.) Dressler	SEL	64835	–25.7
Scaphyglottis panamensis B.R.Adams	MO	3152092	–28.3
Scaphyglottis prolifera (R.Br.) Cogn.	PMA	4275	–27.8
Scaphyglottis prolifera (R.Br.) Cogn.	MO	3479950	–27.1
Scaphyglottis pulchella (Schltr.) L.O.Williams	PMA	42863	–28
Scaphyglottis punctulata (Rchb.f.) C.Schweinf.	MO	3152106	–28.5
Scaphyglottis reflexa Lindl.	MO	3152077	–26.8
Scaphyglottis reflexa Lindl.	MO	4893571	–23.5
Scaphyglottis robusta B.R.Adams	MO	3152076	–30.5
Scaphyglottis sessiliflora B.R.Adams	MO	3303748	–31.7
Scaphyglottis sigmoidea (Ames & C.Schweinf.) B.R.Adams	MO	5313064	–32.1
Scaphyglottis spathulata C.Schweinf.	MO	2353012	–30.9
Scaphyglottis stellata Lodd. ex Lindl.	MO	1882542	–28.1
Scaphyglottis subulata Schltr.	SEL	1592	–25.9
Tribe Arethuseae			
Subtribe Arethusinae			
Arundina graminifolia (D.Don) Hochr.	MO	2172184	–26.7
Tribe Malaxideae			
Crossoglossa blephariglottis (Schltr.) Dressler ex Dodson	MO	4901759	–29.2
Crossoglossa elliptica Dressler	MO	4273409	–33.7
Crossoglossa eustachys (Schltr.) Dressler ex Dodson	SEL	70526	–30.3
Crossoglossa fratra (Schltr.) Dressler ex Dodson	SEL	68232	–32.9
Crossoglossa tenuis Dressler & Dodson	MO	3586973	–32.2
Crossoglossa tipuloides (Lindl.) Dodson	MO	2481253	–31
Liparis elata Lindl.	FLAS	205769	–32.8
Liparis nervosa (Thunb.) Lindl.	PMA	36657	–31.1
Malaxis blephariglottis (Schltr.) Ames	SEL	68647	–32

Table 1. *Continued*

SUBFAMILY			
Tribe			
Species	Herbarium	Accession no.	$\delta^{13}C$ (‰)
Malaxis brachyrrhynchos (Rchb.f.) Ames	MO	2397418	–28.8
Malaxis excavata (Lindl.) Kuntze	MO	3432768	–30.9
Malaxis pandurata (Schltr.) Ames	MO	3311774	–33.3
Malaxis simillima (Rchb.f.) Kuntze	MO	2908231	–28.3
Tribe Cymbidieae			
Subtribe Catasetinae			
Catasetum bicolor Klotzsch	MO	2611986	–26.3
Catasetum viridiflavum Hook.	MO	2049501	–27.7
Clowesia warczewitzii (Lindl. & Paxton) Dodson	MO	955919	–27.6
Cycnoches egertonianum Bateman	PMA	45143	–31.4
Cycnoches warscewiczii Rchb.f.	FLAS	181632	–26.3
Dressleria allenii H.G.Hills	SEL	Live 1976-0056-019A	–25.5
Dressleria suavis (Ames & C.Schweinf.) Dodson	SEL	Live 1990-0738A	–25.8
Dressleria dilecta (Rchb.f.) Dodson	SEL	65792	–25.4
Dressleria eburnea (Rolfe) Dodson	SEL	77420	–25.3
Dressleria helleri Dodson	FLAS	181504	–27.3
Subtribe Cyrtopodiinae			
Cyrtopodium punctatum (L.) Lindl.	MO	5310331	–26.8
Subtribe Eulophiinae			
Eulophia alta (L.) Fawc. & Rendle	MO	2048564	–29.6
**Oeceoclades maculata* (Lindl.) Lindl.	SCZ	12455	–16.7
Subtribe Eriopsidinae			
Eriopsis biloba Lindl.	MO	3332444	–28.5
Subtribe Oncidiinae			
Ada allenii (L.O.Williams ex C.Schweinf.) N.H.Williams	FLAS	218961	–28.8
Ada chlorops (Endres & Rchb.f.) N.H.Williams	MO	4272326	–26.8
Aspasia epidendroides Lindl.	SEL	60171	–26.8
Aspasia principissa Rchb.f.	MO	2105212	–30
Brassia arcuigera Rchb.f.	SEL	32535	–28
Brassia caudata (L.) Lindl.	SEL	56655	–24.2
Brassia gireoudiana Rchb.f. & Warsz.	SEL	12427	–26.1
Brassia verrucosa Bateman ex Lindl. subsp. *verrucosa*	SEL	53583	–26.1
Cischweinfia dasyandra (Rchb.f.) Dressler & N.H.Williams	MO	4901772	–28
Cischweinfia pusilla (C.Schweinf.) Dressler & N.H.Williams	FLAS	218932	–30.2
**Comparettia falcata* Poepp. & Endl.	SEL	13957	–14.3
**Comparettia tuerckheimii* (Schltr.) M.W.Chase & N.H.Williams	SEL	51193	–13.1
Cuitlauzina convallarioides (Schltr.) Dressler & N.H.Williams	MO	2914922	–30.4
Cuitlauzina egertonii (Lindl.) Dressler & N.H.Williams	MO	2167465	–23.2
Cyrtochiloides ochmatochila (Rchb.f.) N.H.Williams & M.W.Chase	MO	3714801	–24.6
Cyrtochiloides panduriformis (Ames & C.Schweinf.) N.H.Williams & M.W.Chase	SEL	64717	–28.8
Cyrtochilum maduroi (Dressler) Senghas	FLAS	219011	–27.3
Erycina crista-galli (Rchb.f.) N.H.Williams & M.W.Chase	MO	3399696	–27
Erycina pumilio (Rchb.f.) N.H.Williams & M.W.Chase	MO	5175516	–23.2
Erycina pusilla (L.) N.H.Williams & M.W.Chase	MO	2928717	–22.8
**Ionopsis satyrioides* (Sw.) Rchb.f.	SEL	56626	–15.5
**Ionopsis utricularioides* (Sw.) Lindl.	SCZ	2197	–12.6
**Leochilus labiatus* (Sw.) Kuntze	SEL	62746	–15.2
**Leochilus leochilinus* (Rchb.f.) M.W.Chase	SEL	68262	–13.6

Table 1. *Continued*

SUBFAMILY			
Tribe			
Species	Herbarium	Accession no.	$\delta^{13}C$ (‰)
**Leochilus leochilinus* (Rchb.f.) Dressler & Williams	PMA	46935	–13.3
**Leochilus scriptus* (Scheidw.) Rchb.f.	SEL	62866	–13.1
**Lockhartia acuta* (Lindl.) Rchb.f.	SCZ	2200	–21.4
Lockhartia amoena Endres & Rchb.f.	SEL	880	–26.1
Lockhartia hercodonta Rchb.f. ex Kraenzl.	SEL	9177	–29.4
Lockhartia micrantha Rchb.f.	SCZ	2201	–24.9
Lockhartia oerstedii Rchb.f.	SEL	57666	–25
Lockhartia pittieri Schltr.	SCZ	12973	–24.6
**Macroclinium lineare* (Ames & C.Schweinf.) Dodson	MO	2286436	–14
Mesospinidium horichii I.Bock	MO	4971080	–29.3
Mesospinidium panamense Garay	MO	4971083	–30.1
Mesospinidium warscewiczii Rchb.f.	SEL	73416	–31.4
Miltoniopsis roezlii (Rchb.f.) God.-Leb.	MO	2937288	–31.2
Miltoniopsis warszewiczii (Rchb.f.) Garay & Dunst.	MO	4272346	–27.8
**Notylia albida* Klotzsch	FLAS	218934	–17.8
**Notylia pentachne* Rchb.f.	MO	1979166	–14.7
**Notylia pittieri* Schltr.	MO	5175874	–15.8
Oncidium abortivoides M.W.Chase & N.H.Williams	MO	3244136	–27.4
Oncidium allenii Dressler	MO	2937527	–29
Oncidium ansiferum Rchb.f.	MO	5325844	–28.7
Oncidium anthocrene Rchb.f.	MO	2937237	–27.9
Oncidium bracteatum Warsz. & Rchb.f.	SEL	68181	–32.9
Oncidium bryolophotum Rchb.f.	MO	3201963	–30.2
Oncidium cariniferum (Rchb.f.) Beer	MO	2941768	–27.7
Oncidium cheirophorum Rchb.f.	MO	2627293	–26.8
Oncidium dichromaticum Rchb.f.	PMA	49320	–29.7
Oncidium ensatum Lindl.	MO	3399703	–27.4
Oncidium exalatum Hágsater	MO	2937525	–28.8
Oncidium fuscatum Rchb.f.	MO	3398418	–32.3
Oncidium hymenanthum (Schltr.) M.W.Chase & N.H.Williams	PMA	49367	–28.2
Oncidium imitans Dressler	FLAS	219162	–28.8
Oncidium integrilabris (Pupulin) M.W.Chase & N.H.Williams	MO	3716786	–27.2
Oncidium isthmi Schltr.	SEL	Live 1996-0169B	–24.5
Oncidium lineoligerum Rchb.f. & Warsz.	MO	5175517	–28.3
Oncidium luteum Rolfe	MO	3393412	–27.5
Oncidium macrobulbon (Kraenzl.) M.W.Chase & N.H.Williams	MO	2894583	–28.8
Oncidium nebulosum Lindl.	MO	3382709	–27.7
Oncidium obryzatoides Kraenzl.	MO	4364574	–28.6
Oncidium panamense Schltr.	FLAS	219026	–28.1
Oncidium parviflorum L.O.Williams	MO	4273711	–31.9
Oncidium pictoides M.W.Chase & N.H.Williams	MO	2999573	–28.1
Oncidium picturatissimum (Kraenzl.) M.W.Chase & N.H.Williams	MO	1934885	–29.7
**Oncidium polycladium* Rchb.f. ex Lindl.	MO	3776494	–17.8
Oncidium punctulatum Dressler	SEL	60039	–27.9
Oncidium schroederianum (O'Brien) Garay & Stacy	MO	3399704	–28.1
Oncidium stenobulbon Kraenzl.	SEL	Live 1990-0803A	–28.4
Oncidium warszewiczii Rchb.f.	MO	4272328	–27
Oncidium zelenkoanum Dressler & Pupulin	FLAS	218812	–26.8
**Ornithocephalus bicornis* Lindl.	FLAS	174569	–11.4
**Ornithocephalus cochleariformis* C.Schweinf.	FLAS	174570	–14.1

Table 1. *Continued*

SUBFAMILY			
Tribe			
Species	Herbarium	Accession no.	$\delta^{13}C$ (‰)
**Ornithocephalus cryptantha* (C.Schweinf. & P.H.Allen) Toscano & Dressler	SEL	6480	–16
**Ornithocephalus dressleri* (Toscano) Toscano & Dressler	FLAS	213134	–19
**Ornithocephalus inflexus* Lindl.	FLAS	174567	–11.8
**Ornithocephalus lankesteri* Ames	SEL	68075	–12.5
**Ornithocephalus powellii* Schltr.	FLAS	174573	–12.9
Otoglossum brevifolium (Lindl.) Garay & Dunst.	MO	4273416	–27.8
Otoglossum globuliferum (Kunth) N.H.Williams & M.W.Chase	MO	3877029	–27.1
Pachyphyllum crystallinum Lindl.	MO	4971074	–30.6
Pachyphyllum hispidulum (Rchb.f.) Garay & Dunst.	MO	3872739	–26.9
**Plectrophora alata* (Rolfe) Garay	FLAS	219042	–17.7
Rhynchostele bictoniensis (Bateman) Soto Arenas & Salazar	MO	3393413	–24.8
**Rodriguezia compacta* Schltr.	MO	1169468	–14.6
**Rodriguezia lanceolata* Ruiz & Pav.	MO	1823279	–15
**Rossioglossum ampliatum* (Lindl.) M.W.Chase & N.H.Williams	MO	2999590	–16
Rossioglossum krameri (Rchb.f.) M.W.Chase & N.H.Williams	SEL	1240	–26.6
Rossioglossum oerstedii (Rchb.f.) M.W.Chase & N.H.Williams	FLAS	187206	–32.1
Rossioglossum schlieperianum (Rchb.f.) Garay & G.C.Kenn	SEL	68350	–26.9
Systeloglossum acuminatum Ames & C.Schweinf.	SEL	66799	–30.7
Systeloglossum costaricense Schltr.	SEL	16892	–28.4
Systeloglossum panamense Dressler & N.H.Williams	MO	4971081	–28.1
Telipogon biolleyi Schltr.	SEL	11325	–27.3
Telipogon boylei (J.T.Atwood) N.H.Williams & Dressler	SEL	68264	–29.6
Telipogon costaricensis Schltr.	FLAS	205827	–25.3
Telipogon storkii Ames & C.Schweinf.	SEL	72276	–29.2
**Trichocentrum ascendens* (Lindl.) M.W.Chase & N.H.Williams	MO	3399702	–16.3
**Trichocentrum caloceras* Endrés & Rchb.f.	SEL	15424	–14.4
**Trichocentrum candidum* Lindl.	PMA	47037	–13.5
**Trichocentrum capistratum* Linden & Rchb.f.	SEL	9184	–12
**Trichocentrum carthagenense* (Jacq.) M.W.Chase & N.H.Williams	MO	2928704	–17.2
**Trichocentrum cebolleta* (Jacq.) M.W.Chase & N.H.Williams	SEL	10497	–11.7
**Trichocentrum costaricensis* Mora-Ret. & Pupulin	SEL	Live 2003-0184A	–14.6
**Trichocentrum lacerum* (Lindl.) ined.	SEL	10539	–11.5
**Trichocentrum nuda* (Bateman ex Lindl.) M.W.Chase & N.H.Williams	MO	2937239	–13.8
**Trichocentrum pfavii* Rchb.f.	SEL	52142	–13.6
Trichopilia punicea Dressler & Pupulin	SEL	Live 2004-0039A	–24.3
Trichopilia similis Dressler	FLAS	178506	–29.3
Trichopilia suavis Lindl. & Paxton	FLAS	205832	–30.2
Trichopilia turialbae Rchb.f.	FLAS	182083	–29.2
**Trizeuxis falcata* Lindl.	SEL	11352	–12.8
Subtribe Maxillariinae			
Camaridium adolphi Schltr.	SEL	80019	–24.8
Camaridium allenii (L.O.Williams) M.A.Blanco	SEL	56397	–29.5
Camaridium ampliflorum (C.Schweinf.) M.A.Blanco	SEL	84849	–31.1
Camaridium anceps (Rchb.f.) M.A.Blanco	SEL	68148	–24.9
Camaridium anceps (Rchb.f.) M.A.Blanco	SEL	67950	–31
Camaridium biolleyi (Schltr.) Schltr.	SEL	84898	–26.1
Camaridium bracteatum (Schltr.) Schltr.	SEL	65933	–28.6
Camaridium bradeorum Schltr.	SEL	51191	–32.5
Camaridium brenesii Schltr.	SEL	71468	–30.1

Table 1. *Continued*

SUBFAMILY			
Tribe			
Species	Herbarium	Accession no.	$\delta^{13}C$ (‰)
Camaridium brevilabium (Ames & Correll) M.A.Blanco	SEL	85591	–32
Camaridium burgeri (J.T.Atwood) M.A.Blanco	SEL	53523	–27.4
Camaridium campanulatum (C.Schweinf.) M.A.Blanco	SEL	79661	–25.7
Camaridium costaricense Schltr.	SEL	79809	–30.2
**Camaridium ctenostachys* (Rchb.f) Schltr.	FLAS	212900	–21.7
Camaridium cucullatum (Lindl.) M.A.Blanco	MO	4909652	–25.7
Camaridium dendrobioides Schltr.	FLAS	212911	–28.2
Camaridium dichotomum Schltr.	SEL	72812	–30.4
Camaridium falcatum (Ames & Correll) M.A.Blanco	SEL	80324	–28.1
Camaridium fragrans (J.T.Atwood) M.A.Blanco	SEL	84868	–27.7
Camaridium gomezianum (J.T.Atwood) M.A.Blanco	SEL	56309	–30.3
Camaridium horichii (Senghas) M.A.Blanco	SEL	80309	–24.8
Camaridium imbricatum Schltr.	SEL	71982	–30.8
Camaridium inauditum (Rchb.f.) M.A.Blanco	SEL	70973	–25.8
Camaridium lankesteri (Ames) M.A.Blanco	SEL	84858	–28.5
Camaridium lankesteri (Ames) M.A.Blanco	SEL	84896	–24.2
Camaridium longicolumna (J.T.Atwood) M.A.Blanco	MO	2928592	–28.7
Camaridium lutheri (J.T.Atwood) M.A.Blanco	SEL	84855	–28.4
Camaridium micranthum M.A.Blanco	SEL	85537	–31.7
Camaridium microphyton (Schltr.) M.A.Blanco	SEL	84853	–28.7
Camaridium monteverdense (J.T.Atwood & G.Barboza) M.A.Blanco	SEL	73752	–29.6
Camaridium neglectum (Schltr.) M.A.Blanco	MO	1980691	–28.8
Camaridium nutantiflorum Schltr.	SEL	67690	–32.1
Camaridium obscurum (Linden & Rchb.f.) M.A.Blanco	SEL	85539	–26.6
Camaridium ochroleucum Lindl.	MO	1941309	–25.4
Camaridium paleatum (Rchb.f.) M.A.Blanco	SEL	56395	–31.1
Camaridium pygmaeum M.A.Blanco	SEL	52183	–27.9
Camaridium ramonense (Schltr.) M.A.Blanco	SEL	84863	–29.7
Camaridium scalariforme (J.T.Atwood) M.A.Blanco	SEL	83980	–29
Camaridium sigmoideum (C.Schweinf.) M.A.Blanco	SEL	71978	–26.7
Camaridium stenophyllum (Schltr.) M.A.Blanco	SEL	85542	–32.1
Camaridium suaveolens (Barringer) M.A.Blanco	FLAS	213078	–26.8
Camaridium tigrinum (C.Schweinf.) M.A.Blanco	SEL	69030	–30.8
Camaridium tuberculare (J.T.Atwood) M.A.Blanco	SEL	79818	–33.2
Camaridium tutae (J.T.Atwood) M.A.Blanco	SEL	93558	–28.1
Camaridium vaginale (Rchb.f.) M.A.Blanco	SEL	72771	–33.3
Camaridium valerioi (Ames & C.Schweinf.) M.A.Blanco	SEL	56324	–27.7
Camaridium vittariifolium (L.O.Williams) M.A.Blanco	SEL	1114	–29
Christensonella uncata (Lindl.) Szlach.	SEL	54571	–29.7
Cryptocentrum calcaratum (Schltr.) Schltr.	MO	2941738	–22.9
Cryptocentrum flavum Schltr.	MO	1934875	–28.1
Cryptocentrum gracilipes Schltr.	MO	4964577	–28.2
Cryptocentrum gracillimum Ames & C.Schweinf.	SEL	66794	–29.1
Cryptocentrum latifolium Schltr.	SEL	196	–25.6
Cryptocentrum lehmannii (Rchb.f.) Garay	SEL	53591	–24.2
Cryptocentrum standleyi Ames	SEL	14003	–32.6
**Heterotaxis crassifolia* Lindl.	SEL	59784	–14.7
Heterotaxis discolor (Lodd. ex Lindl.) Ojeda & Carnevali	PMA	46822	–29.1
Heterotaxis maleolens (Schltr.) Ojeda & Carnevali	SEL	67303	–23.9
**Heterotaxis valenzuelana* (A.Rich.) Ojeda & Carnevali	SEL	10315	–21.8

Table 1. *Continued*

SUBFAMILY			
Tribe			
Species	Herbarium	Accession no.	$\delta^{13}C$ (‰)
Inti bicallosa (Rchb.f.) M.A.Blanco	FLAS	212860	–28.6
Inti chartacifolia (Ames & C. Schweinf.) M.A.Blanco	SEL	67341	–30
Lycaste campbellii C.Schweinf.	SEL	Live 1990-560A	–24.6
Lycaste leucantha (Klotzsch) Lindl.	MO	3494248	–29.1
Lycaste macrophylla (Poepp. & Endl.) Lindl.	PMA	4386	–27.4
Lycaste powellii Schltr.	MO	4305418	–29.1
Lycaste schilleriana Rchb.f.	MO	2628639	–30.3
Lycaste tricolor Rchb.f.	SEL	9488	–26.1
Mapinguari longipetiolatus (Ames & C.Schweinf.) Carnevali & R.Singer	SEL	66540	–31
Maxillaria acostae Schltr.	SEL	56446	–28.7
Maxillaria amesiana hort.	FLAS	212837	–28.3
Maxillaria angustisegmenta Ames & C.Schweinf.	SEL	56355	–27.3
Maxillaria angustissima Ames, F.T.Hubb. & C.Schweinf.	SEL	81901	–29.2
Maxillaria arachnitiflora Ames & C.Schweinf.	SEL	56656	–28.8
Maxillaria brachybulbon Schltr.	MO	2241365	–26.6
Maxillaria calantha Schltr.	FLAS	212874	–27.8
Maxillaria chionantha J.T.Atwood	FLAS	212884	–30
Maxillaria confusa Ames & C.Schweinf.	SEL	73648	–26
Maxillaria cryptobulbon Carnevali & J.T.Atwood	SEL	56367	–28.8
Maxillaria endresii Rchb.f.	SEL	57560	–29
Maxillaria exaltata (Kraenzl.) C.Schweinf.	SEL	71467	–26.8
Maxillaria fuerstenbergiana Schltr.	MO	2117310	–26.9
Maxillaria galantha J.T.Atwood & Carnevali	MO	3303806	–27.2
Maxillaria grandiflora (Kunth) Lindl.	FLAS	212947	–24.8
Maxillaria hennisiana Schltr.	FLAS	212957	–28.7
Maxillaria lepidota Lindl.	FLAS	212976	–29.1
Maxillaria longiloba (Ames & C.Schweinf.) J.T.Atwood	SEL	71303	–28.2
Maxillaria longipes Lindl.	FLAS	212982	–29.7
Maxillaria meridensis Lindl.	SEL	67335	–26
Maxillaria minor (Schltr.) L.O.Williams	SEL	71060	–28.7
Maxillaria nutans Lindl.	FLAS	213012	–28
Maxillaria porrecta Lindl.	SEL	959	–30.3
Maxillaria ramonensis Schltr.	SEL	76268	–31.4
Maxillaria ramosa Ruiz & Pav.	SEL	67916	–28.2
Maxillaria reichenheimiana Endres & Rchb.f.	FLAS	213049	–31
Maxillaria ringens Rchb.f.	SEL	52172	–28.1
Maxillaria rodrigueziana J.T.Atwood	MO	2940838	–28.7
Maxillaria rubioi Dodson	FLAS	213058	–31.5
Maxillaria sanderiana Rchb.f. ex Sander	FLAS	213065	–28
Maxillaria setigera Lindl.	FLAS	212875	–28.1
Maxillaria turkeliae Christenson	FLAS	213085	–27.9
Maxillariella acervata (Rchb.f.) M.A.Blanco & Carnevali	MO	4336352	–29.9
Maxillariella alba (Hook.f.) M.A.Blanco & Carnevali	SEL	80303	–29.7
Maxillariella caespitifica (Rchb.f.) M.A.Blanco & Carnevali	SEL	85592	–31.5
Maxillariella costaricensis (Schltr.) M.A.Blanco & Carnevali	SEL	72570	–29.7
Maxillariella diuturna (Ames & C. Schweinf.) M.A.Blanco & Carnevali	SEL	45578	–28.9
Maxillariella lawrenceana (Rolfe) M.A.Blanco & Carnevali	FLAS	212972	–27.3
Maxillariella linearifolia (Ames & C. Schweinf.) M.A.Blanco & Carnevali	SEL	71084	–29.6

Table 1. *Continued*

SUBFAMILY			
Tribe			
Species	Herbarium	Accession no.	$\delta^{13}C$ (‰)
Maxillariella oreocharis (Schltr.) M.A.Blanco & Carnevali	SEL	61433	–27.4
Maxillariella ponerantha (Rchb.f.) M.A.Blanco & Carnevali	FLAS	No number	–29.1
Maxillariella sanguinea (Rolfe) M.A.Blanco & Carnevali	MO	1227035	–27
Maxillariella tenuifolia (Lindl.) M.A.Blanco & Carnevali	FLAS	213082	–25.3
Maxillariella variabilis (Bateman ex Lindl.) M.A.Blanco & Carnevali	SEL	61459	–29.6
Mormolyca acutifolia (Lindl.) M.A.Blanco	MO	2166550	–31.1
Mormolyca dressleriana (Carnevali & J.T.Atwood) M.A.Blanco	SEL	79814	–28.6
Mormolyca hedwigiae (Hamer & Dodson) M.A.Blanco	SEL	57540	–30.2
Mormolyca moralesii (Carnevali & J.T.Atwood) M.A.Blanco	SEL	88715	–32.3
Mormolyca ringens (Lindl.) Gentil	MO	3587134	–24.1
Mormolyca rufescens (Lindl.) M.A.Blanco	MO	2481151	–27.2
Nitidobulbon nasutum (Rchb.f.) Ojeda & Carnevali	SEL	56322	–32.3
Ornithidium adendrobium (Rchb.f.) M.A.Blanco & Ojeda	SEL	85549	–29.9
Ornithidium aureum Poepp. & Endl.	MO	2929223	–27.9
Ornithidium conduplicatum Ames & C.Schweinf.	SEL	85589	–27.3
Ornithidium fulgens Rchb.f.	SCZ	2208	–26
Ornithidium nicaraguense (Hamer & Garay) M.A.Blanco & Ojeda	SEL	67919	–25.9
Ornithidium pittieri Ames	SEL	56318	–29.3
Rhetinantha aciantha (Rchb.f.) M.A.Blanco	MO	2117309	–23.2
Rhetinantha acuminata (Lindl.) M.A.Blanco	FLAS	212827	–23.7
Rhetinantha friedrichsthalii (Rchb.f) M.A.Blanco	SEL	66963	–26
Rhetinantha scorpioidea (Kraenzl.) M.A.Blanco	SEL	15510	–25.7
Trigonidium egertonianum Bateman ex Lindl.	MO	1976848	–29
Trigonidium insigne Rchb.f. ex Benth. & Hook.f.	SEL	1918	–26
Trigonidium lankesteri Ames	FLAS	212813	–25.4
Trigonidium riopalenquense Dodson	MO	2937380	–31.2
Xylobium colleyi (Bateman ex Lindl.) Rolfe	MO	4901770	–29.5
Xylobium elongatum (Lindl. & Paxton) Hemsl.	SEL	68043	–32.7
Xylobium foveatum (Lindl.) G.Nicholson	FLAS	178752	–29.7
Xylobium sulfurinum (Lem.) Schltr.	MO	2107251	–27
Subtribe Stanhopeinae			
Coryanthes maculata Hook.	MO	4302493	–27.8
Gongora armeniaca (Lindl.) Rchb.f.	SEL	Live 2003-0159A	–27.2
Gongora claviodora Dressler	FLAS	205756	–29.8
Gongora fulva Lindl.	MO	955901	–28.9
Gongora gibba Dressler	MO	1934888	–30
Gongora horichiana Fowlie	FLAS	178784	–30.4
Gongora quinquenervis Ruiz & Pav.	FLAS	165503	–25.1
Houlletia odoratissima Linden ex Lindl. & Paxton	PMA	4054	–28.1
Houlletia tigrina Linden ex Lindl.	SEL	Live 2002-0133A	–29.9
Kegeliella atropilosa L.O.Williams & A.H.Heller	SEL	Live 1994-0371C	–27.3
Polycycnis gratiosa Endres & Rchb.f.	MO	2481104	–30.5
Polycycnis muscifera (Lindl. & Paxton) Rchb.f.	MO	2926914	–32.5
Polycycnis ornata Garay	MO	1941570	–30.8
Stanhopea avicula Dressler	FLAS	178208	–28
Stanhopea cirrhata Lindl.	SEL	Live 1975-0023-041B	–25.1
Stanhopea costaricensis Rchb.f.	MO	1782468	–28.9
Stanhopea ecornuta Lem.	MO	4336209	–30.2
Stanhopea panamensis N.H.Williams & W.M.Whitten	SEL	Live 1976-0056-016A	–28
Stanhopea pulla Rchb.f.	FLAS	181688	–23.1

Table 1. *Continued*

SUBFAMILY			
Tribe			
Species	Herbarium	Accession no.	$\delta^{13}C$ (‰)
Stanhopea wardii Lodd. ex Lindl.	SEL	Live 1975-0023-031A	–29.3
Subtribe Coeliopsidinae			
Coeliopsis hyacinthosma Rchb.f.	MO	4273419	–30.2
Peristeria elata Hook.	MO	3432826	–27.8
Subtribe Zygopetalinae			
Chondrorhyncha bicolor Rolfe	MO	3714803	–28.9
Chondrorhyncha crassa Dressler	MO	4622799	–32.4
Chondrorhyncha reichenbachiana Schtr.	FLAS	152213	–26.4
Chondroscaphe atrilinguis Dressler	PMA	54869	–31.7
Cochleanthes aromatica (Rchb.f.) R.E.Schult. & Garay	SEL	68352	–29.8
Cryptarrhena guatemalensis Schltr.	MO	2622834	–29.1
Cryptarrhena lunata R.Br.	MO	3496948	–29
Dichaea ciliolata Rolfe	MO	3484233	–27.2
Dichaea costaricensis Schltr.	MO	4893570	–28.8
Dichaea cryptarrhena Rchb.f. ex Kraenzl.	SEL	64574	–26.8
Dichaea dammeriana Kraenzl.	MO	3114545	–32.4
Dichaea dressleri Folsom	MO	2928645	–31.3
Dichaea elliptica Dressler & Folsom	MO	3595561	–31.9
Dichaea fragrantissima Folsom	MO	2814449	–28.4
Dichaea globosa Dressler & Pupulin	FLAS	212758	–25
Dichaea hystricina Rchb.f.	MO	4893574	–28.3
Dichaea lankesteri Ames	FLAS	185771	–28.4
Dichaea morrisii Fawc. & Rendle	SEL	68107	–28.9
Dichaea muricatoides Hamer & Garay	FLAS	205742	–26.1
Dichaea neglecta Schltr.	MO	4964297	–31
Dichaea oxyglossa Schltr.	SEL	68896	–29.7
Dichaea panamensis Lindl.	SEL	56506	–32.9
Dichaea poicillantha Schltr.	SEL	63725	–23.2
Dichaea standleyi Ames	FLAS	185774	–30.3
Dichaea tenuifolia Schltr.	MO	4963040	–32.4
Dichaea trichocarpa (Sw.) Lindl.	FLAS	202842	–27.4
Dichaea trulla Rchb.f.	MO	2937231	–30.4
Dichaea tuerckheimii Kraenzl.	MO	2814172	–29.7
Dichaea violacea Folsom	MO	2923116	–29.8
Euryblema anatonum (Dressler) Dressler	MO	2937369	–33.8
Galeottia grandiflora A.Rich.	MO	1947355	–29.4
Huntleya burtii (Endres & Rchb.f.) Rolfe	MO	2240379	–27.7
Huntleya fasciata Fowlie	SCZ	2193	–25.6
Huntleya lucida (Rolfe) Rolfe	MO	3595549	–28.7
Kefersteinia auriculata Dressler	MO	4901757	–31.5
Kefersteinia costaricensis Schltr.	MO	4893555	–27.7
Kefersteinia excentrica Dressler & Mora-Ret.	MO	3716832	–26.5
Kefersteinia lactea (Rchb.f.) Schltr.	MO	4893548	–29.1
Koellensteinia kellneriana Rchb.f.	MO	1780929	–26.2
Pescatoria cerina (Lindl. & Paxton) Rchb.f.	FLAS	152210	–31.9
Pescatoria dayana Rchb.f.	MO	2926912	–30.9
Stenotyla picta (Rchb.f.) Dressler	SEL	67925	–32
Warczewiczella discolor (Lindl.) Rchb.f.	FLAS	181609	–22.6
Warczewiczella lipscombiae (Rolfe) Fowlie	FLAS	181757	–26.1

Table 1. *Continued*

SUBFAMILY			
Tribe			
Species	Herbarium	Accession no.	$\delta^{13}C$ (‰)
Warrea costaricensis Schltr.	MO	4893556	–30.2
Tribe Vandeae			
Subtribe Polystachyinae			
Polystachya foliosa (Hook.) Rchb.f.	MO	3887632	–28.4
Subtribe Angraecinae			
**Campylocentrum brenesii* Schltr.	SEL	70631	–19.2
**Campylocentrum micranthum* (Lindl.) Rolfe	SCZ	2117	–15.3
**Campylocentrum panamense* Ames	SEL	59739	–13.6
**Campylocentrum schiedei* (Rchb.f.) Benth.ex Hemsl.	SEL	70629	–13.5
Subtribe Dendrobiinae			
Bulbophyllum aristatum (Rchb.f.) Hemsl.	SEL	56821	–28.1
Subtribe Collabiinae			
Calanthe calanthoides (A.Rich. & Galeotti) Hamer & Garay	SEL	68932	–32
Calanthe mexicana Rchb.f.	FLAS	82929	–29
Spathoglottis plicata Blume	MO	5345753	–29.9

*Indicates strong crassulacean acid metabolism (CAM) species.
Herbaria are listed as follows: the Missouri Botanical Gardens Herbarium (MO), the Marie Selby Botanical Gardens Herbarium (SEL), the University of Florida Herbarium (FLAS), the University of Panama Herbarium (PMA) and the Smithsonian Tropical Research Institute Herbarium (SCZ). Live specimens and reference numbers correspond to species available at the Selby Botanical Gardens' live collection. Synonym names are provided in Appendix S1 (available online).

to reveal the extent of weak CAM species likely to be present within the C_3 isotopic range. Because $\delta^{13}C$ was used as a screening method, we cannot account for those species that have $\delta^{13}C$ characteristic of C_3 species, but obtain up to one third of their carbon through nocturnal CO_2 fixation, as is the case with weak CAM and some facultative CAM species (Winter & Holtum, 2002; Silvera *et al*., 2005; Winter *et al*., 2008; Winter & Holtum, 2007). Previous work in Orchidaceae has shown that roughly 30% of species with isotopic values characteristic of C_3 photosynthesis can show weakly expressed CAM. For example, a number of species in the genera *Brassia* R.Br., *Cischweinfia* Dressler & N.H.Williams, *Coryanthes* Hook., *Dimerandra* Schltr., *Eriopsis* Lindl., Maxillaria Ruiz & Pav., *Mormodes* Lindl., *Peristeria* Hook., *Scaphyglottis*, *Sobralia*, *Trichopilia* Lindl. and *Trigonodium* Lindl. exhibited nocturnal increases in leaf tissue acidity indicative of CAM although $\delta^{13}C$ values were in the C_3 range (Silvera *et al*., 2005). The detection of weak CAM requires the study of live specimens in which either titratable acidity and/or net CO_2 exchange is measured and, thus, requires more elaborate experimental sampling methods than $\delta^{13}C$ screening of herbarium specimens (Sinclair, 1983; Winter & Holtum, 2002).

The previous report of 20% strong CAM species among 214 mainly Central American species studied by Silvera *et al*. (2005), compared with 9.5% strong CAM species in the current much larger survey, may be explained by the fact that the former study had a bias towards commercially valuable lowland orchid species adapted to drier sites (Silvera *et al*., 2009). In contrast, the current, more complete study considered orchids from a much broader range of habitats, including high elevation sites, where strong CAM species occur less frequently. Nonetheless, if the predicted number of weak CAM species were added to the estimates of strong CAM species in the current study, then the total number of species exhibiting an ability to perform CAM in the Panama–Costa Rica region would be expected to increase markedly above the 9.5% established by strong CAM species alone.

In a previous extensive survey of CAM in the neotropical family Bromeliaceae, Crayn *et al*. (2004) found strong CAM in 826 of 1873 bromeliad species (44%), which surpasses the proportion of strong CAM species for orchids of Panama and Costa Rica. In Panama and

Table 2. List of orchid genera containing species with crassulacean acid metabolism (CAM)

Orchid Genus	Reference
Acianthera Scheidw.	This study
Aerangis Rchb.f.	Smith & Winter (1996)
Aeranthes Lindl.	Smith & Winter (1996)
Aerides Lour.	Smith & Winter (1996)
Angraecum Bory	Smith & Winter (1996)
Arachnis Blume	Smith & Winter (1996)
Ascocentrum Schltr.	Smith & Winter (1996)
Aspasia Salisb.	Silvera *et al*. (2005)
Barkeria Knowles & Westc.	This study
Brassavola Adans.	Smith & Winter (1996); Zotz & Ziegler (1997); Silvera *et al*. (2005); this study
Brassia R.Br.	Silvera *et al*. (2005)
Bulbophyllum Thouars	Smith & Winter (1996); Silvera *et al*. (2005)
Cadetia Gaudich.	Smith & Winter (1996)
Calanthe R.Br.	Smith & Winter (1996)
Camaridium Lindl.	This study
Campylocentrum Benth.	Zotz & Ziegler (1997); Zotz (2004); this study
Cattleya Lindl.	Smith & Winter (1996); Zotz & Ziegler (1997); Silvera *et al*. (2005); this study
Caularthron Raf.	Smith & Winter (1996); Zotz & Ziegler (1997); Zotz (2004); this study
Chiloschista Lindl.	Smith & Winter (1996)
Cischweinfia Dressler & N.H.Williams	Silvera *et al*. (2005)
Coelogyne Lindl.	Smith & Winter (1996); Silvera *et al*. (2005)
Comparettia Poepp. & Endl.	This study
Coryanthes Hook.	Silvera *et al*. (2005)
Cymbidium Sw.	Smith & Winter (1996)
Cyrtopodium R.Br.	Smith & Winter (1996)
Dendrobium Sw.	Smith & Winter (1996)
Dendrophylax Rchb.f. (= *Polyradicion*)	Smith & Winter (1996)
Dimerandra Schltr.	Smith & Winter (1996); Zotz & Ziegler (1999); Silvera *et al*. (2005)
Elleanthus C.Presl	This study
Encyclia Hook.	Smith & Winter (1996); Silvera *et al*. (2005); this study
Epidendrum L.	Smith & Winter (1996); Zotz & Ziegler (1997); Zotz (2004); Silvera *et al*. (2005); this study
Eria Lindl.	Smith & Winter (1996)
Eriopsis Lindl.	Silvera *et al*. (2005)
Eulophia R.Br. (= *Lissochilus*)	Smith & Winter (1996)
Flickingeria A.D.Hawkes	Smith & Winter (1996)
Guarianthe Dressler & W.E.Higgins	Silvera *et al*. (2005); this study
Heterotaxis Lindl.	Silvera *et al*. (2005); this study
Ionopsis Kunth	Silvera *et al*. (2005); this study
Jacquiniella Schltr.	Zotz (2004)
Jumellea Schltr.	Smith & Winter (1996)
Laelia Pers.	Smith & Winter (1996); this study
Leochilus Knowles & Westc.	This study
Lockhartia Hook.	Zotz & Ziegler (1997); Zotz (2004); Silvera *et al*. (2005); this study
Luisia Gaudich.	Smith & Winter (1996)
Macroclinium Barb.Rodr. ex Pfltz.	Silvera *et al*. (2005); this study
Maxillaria Ruiz & Pav.	Smith & Winter (1996); Zotz & Ziegler (1997); Zotz (2004); Silvera *et al*. (2005)
Microcoelia Lindl.	Smith & Winter (1996)
Micropera Lindl.	Smith & Winter (1996)
Mobilabium Rupp	Smith & Winter (1996)
Mormodes Lindl.	Silvera *et al*. (2005)

Table 2. *Continued*

Orchid Genus	Reference
Myoxanthus Poepp. & Endl.	This study
Myrmecophila Rolfe	This study
Notylia Lindl.	Zotz & Ziegler (1997); Zotz (2004); Silvera *et al*. (2005); this study
Oeceoclades Lindl.	This study
Oeonia Lindl.	Smith & Winter (1996)
Oncidium Sw.	Smith & Winter (1996); Silvera *et al*. (2005); this study
Ornithocephalus Hook.	Zotz & Ziegler (1997); Zotz (2004); Silvera *et al*. (2005); this study
Paphiopedilum Pfitzer	Smith & Winter (1996)
Peristeria Hook.	Silvera *et al*. (2005)
Phalaenopsis Blume	Smith & Winter (1996)
Pholidota Lindl.	Smith & Winter (1996)
Plectorrhiza Dockrill	Smith & Winter (1996)
Plectrophora H.Focke	This study
Pleurothallis R.Br.	Smith & Winter (1996); Zotz & Ziegler (1997); Zotz (2004); Silvera *et al*. (2005); this study
Prosthechea Knowles & Westc.	Silvera *et al*. (2005)
Rhinerrhiza Rupp	Smith & Winter (1996)
Robiquetia Gaudich.	Smith & Winter (1996)
Rodriguezia Ruiz & Pav.	Zotz & Ziegler (1997); Silvera *et al*. (2005); this study
Rossioglossum (Schltr.) Garay & G.C.Kenn.	This study
Saccolabiopsis J.J.Sm.	Smith & Winter (1996)
Saccolabium Blume	Smith & Winter (1996)
Sarcochilus R.Br.	Smith & Winter (1996)
Scaphyglottis Poepp. & Endl.	Silvera *et al*. (2005)
Schoenorchis Blume	Smith & Winter (1996)
Sobralia Ruiz & Pav.	Silvera *et al*. (2005)
Solenangis Schltr.	Smith & Winter (1996)
Sophronitis Lindl.	Smith & Winter (1996)
Specklinia Lindl.	Silvera *et al*. (2005)
Taeniophyllum Blume	Smith & Winter (1996)
Thrixspermum Lour.	Smith & Winter (1996)
Thunia Rchb.f.	Smith & Winter (1996
Trichocentrum Poepp. & Endl.	Zotz (2004); Silvera *et al*. (2005); this study
Trichoglottis Blume	Smith & Winter (1996)
Trichopilia Lindl.	Silvera *et al*. (2005)
Trigonidium Lindl.	Silvera *et al*. (2005)
Trizeuxis Lindl.	This study
Tuberolabium Yamam.	Smith & Winter (1996)
Vanda Jones ex R.Br.	Smith & Winter (1996)
Vanilla Mill.	Smith & Winter (1996); Zotz & Ziegler (1997); Silvera *et al*. (2005); this study

This list has been updated from that of Smith & Winter (1996), using a literature search and the results of this study.

Costa Rica, most collection sites for orchids receive well over 1000 mm of annual precipitation and there is little coverage of tropical and subtropical dry forests, in which CAM epiphytes are favoured.

Our study represents the largest $\delta^{13}C$ survey of orchids ever performed and provides a fairly representative picture of the occurrence of strong CAM among the local flora of Panama and Costa Rica. Even so, this survey covers only 4% of the estimated total number of orchid species known worldwide. Further extensive $\delta^{13}C$ sampling of orchid species from other regions is needed to improve our knowledge of the incidence and functional significance of CAM in this large family of vascular plants.

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SUPPORTING INFORMATION

Additional Supporting Information may be found in the online version of this article:

Appendix S1. Leaf carbon isotopic values (‰) and voucher information from 1002 orchid species of Panama and Costa Rica organized alphabetically.

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