

Synthesis

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The critical question has been asked if it makes sense to devote a book-monograph to a single genus of neotropical trees. The diversity of tropical tree species is very large indeed. Why just select one, and why just select *Clusia*? One strong motivation was given by the fact that *Clusias* are the only trees performing crassulacean acid metabolism (Chap. 1). This in itself would not justify singling out *Clusia* for its own book. However, it turned out that this fact prompted a number of plant scientists for the first time in almost 25 years to study all possible aspects of *Clusia*'s biology in presumably quite a unique way, not only covering a very large number of aspects but also integrating them in a remarkable synthesis. It happened that in the research teams, phytogeographers, phytosociologists and ecologists became familiar with physiological approaches and physiologists took an immediate interest in community structures, aiming to advance from autecology to physiological synecology. The field-laboratory-field-laboratory-field-etc. ping pong worked effectively in all teams involved in making observations and in increasing curiosity in the field, to develop interpretations and hypotheses and to test them in laboratories and phyto-chambers, to come back to the field and check the validity of plant compartment under controlled conditions for performance in the natural environments and to increase the precision of observations. This is an ongoing process in *Clusia* research and, although we try to present here the most recent and up to date knowledge on *Clusia*, I know that while I am writing these lines new discoveries are being made and new interpretations are being formed. In the book we present a reviewing style of chapters often enriched by the presentation of new and unpublished information, which is particularly the case in the fields of nurse plants (Chap. 4), reproductive biology (Chap. 5), phylogeny (Chap. 6), population genetics (Chap. 7), mycorrhiza (Chap. 10) and biological timing (Chap. 11). We are happy to present our material in this way because it underlines the dynamics of the field of *Clusia*-research.

With the integrating synthesis of the knowledge available, *Clusia* is really becoming a general example for almost all facets of plant biology. I prefer

“example” and hesitate to say “model”, because the current model fashion bears many dangers vis à vis biological diversity. Anatomy and morphology bear out structure-function relationships (Chap. 2), e.g. particularly in relation to plant architecture and modes of photosynthesis. The phylogeography of *Clusia* displays complicated relations of plant distribution in tropical America (Chap. 3). On a smaller scale the nurse plant concept can be advanced with the example of *Clusia* revealing new aspects of the built up of community structures (Chap. 4). Reproductive biology of *Clusia* unravels relations of specific reproductive mechanisms to plant success at the community level (Chap. 5). Molecular phylogeny and population genetics show relations of genetic plasticity and diversity (Chaps. 6 and 7) which can be related to ecophysiological flexibility (Chap. 9). Thus, *Clusia* may provide a unique example for the discussion of the mechanisms of diversity where stress is an important factor but not a single dominating environmental parameter and rather a multi-parameter interaction and network is decisive. Photosynthetic activities of *Clusias* cover all possible ramifications with different modes of photosynthesis and photosynthetic physiotypes, all variants of crassulacean acid metabolism (CAM) and its metabolic diversity, photorespiration, photoprotection and photoinhibition (Chap. 8). Mineral nutrition (Chap. 9) relates to the biotic interactions of mycorrhiza (Chap. 10). Responses to environmental factors show basic features (Chap. 8) as well as specific adaptations (Chap. 9). Anecdotic reports on the performance of *Clusias* in comparison to other shrubs and trees of similar life form in more than a dozen of different habitats begin to add up to a general picture, where CAM appears to be par-



Fig. Syn.1. The mistletoe *Phthirusa ovata* growing on *Clusia criuva* in a gallery forest in the cerrado near Brasilia, Brazil. In the right hand picture one can see the mistletoe shoot winding around the *Clusia* shoot

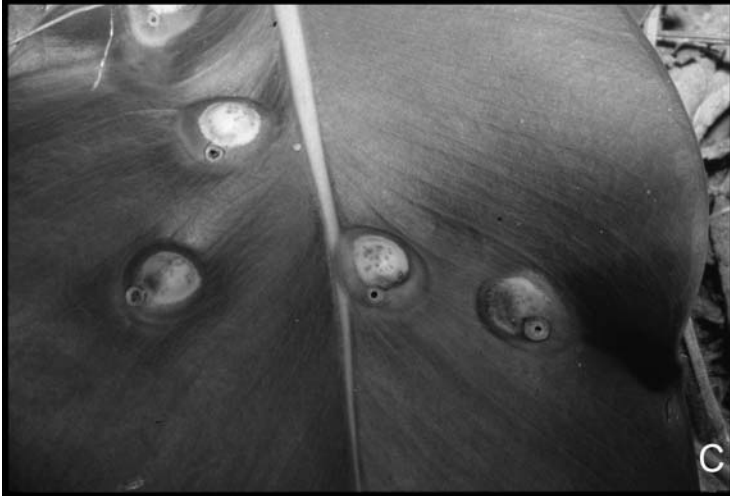
ticularly beneficial for performance at the community level due to its intrinsic flexibility. However, at the same time new questions emerge as to which traits in addition to modes of photosynthesis may govern behaviour (Chap. 9). The biological clock of *Clusia* has unique dynamics of rapid dampening. This raises questions in relation to endogenous rhythmicity in different modes of photosynthesis. It reiterates the fundamental considerations of the function of endogenous biological timing and the intriguing question if rhythmic timing may not even be a hindrance for flexibility under varying environmental stress situations (Chap. 11).

One aspect that did not come up in this book was the question of the biological interactions of *Clusia* with potential predators. In the field *Clusia* bushes and trees mostly look very healthy and intact. We have very rarely seen traces of predation. Possibly the strong latex production of all *Clusias* is quite protective. *Clusias* may, however, be heavily invaded by mistletoes (Fig. Syn.1). Measurements were performed of the mistletoe *Phthirusa ovata* (Pohl) Eichl. on *Clusia criuva* Camb. in the gallery forest along a river in the cerrados near Brasilia, Brazil (see Sect. 9.4.2.4). It was seen that at low photosynthetically active radiation the actual apparent photosynthetic electron transport rates, ETR (Eq. 8.1, Sect. 8.1), were similar for both the *Clusia* host and the mistletoe, but intrinsic photosynthetic capacity as given by maximum ETR obtained from light saturation curves was superior in the host. The mistletoe had more negative $\delta^{13}\text{C}$ values (Eq. 8.3, Sect. 8.2) than the host, which implies that it had a lower overall water use efficiency and worked at higher average internal CO_2 -concentration (Table Syn.1). These are very typical mistletoe host relationships (Lüttge et al. 1998).

We also found that sometimes *Clusia* may be strongly affected by gall wasps (Fig. Syn.2). This can be quite specific. In the Atlantic rain forest in Brazil (Sect. 9.4.2.10) we found that among four species of *Clusia* only *C. aemygdioi* Silva et Weinberg was regularly seen to be the host of gall wasps (Figs. Syn.2B and C). Using a chlorophyll fluorescence imaging system we have studied photosynthetic capacity of the leaves across the galls which shows an interesting profile (Fig. Syn.3). Relative efficiency of photosystem II, Φ_{PSII} is particularly high in a ring around the gall and higher there than in the normal leaf tissue, while it sharply drops in the gall tissue itself. Possibly pho-

Table Syn.1. Photosynthesis of the mistletoe *Phytirusa ovata* in relation to its host *Clusia criuva* in a gallery forest in the cerrado near Brasilia, Brazil. Data given are the differences of values of mistletoe minus host. (After data of Lüttge et al. 1998)

Apparent electron transport rate at ca. 100 μmol quanta $\text{m}^{-2} \text{s}^{-1}$ [$\mu\text{mol} \text{m}^{-2} \text{s}^{-1}$]	10
Maximum intrinsic apparent electron transport rate [$\mu\text{mol} \text{m}^{-2} \text{s}^{-1}$]	-125
$\delta^{13}\text{C}$ [‰]	-5.18
Internal CO_2 partial pressure [Pa/MPa]	80



tosynthesis around the galls is stimulated for providing supplies to the gall larvae. (The unpublished data of this work remain to be processed.)

The final if not the initial question always asked in these days is “what is all this good for”? It is good for our monographic knowledge of *Clusia*. It is good – as I tried to allude to above – for our general knowledge of plant biology. *Clusia* does not appear to be a commercial bestseller. It is used practically in various ways. With its great adaptive flexibility and as a nurse plant it is appre-

Fig. Syn.3. A Leaf of *C. aemygdioi* with galls. B The developed gall encircled in A. C Chlorophyll fluorescence image of the relative efficiency of photosystem II (Φ_{PSII}) of the part of the gall marked in B; the bar indicates minimal and maximal values of Φ_{PSII} . D The intensity of Φ_{PSII} is also shown as a three dimensional profile, where the heights represent the relative intensity. (Originals by courtesy of Heitor M. Duarte)

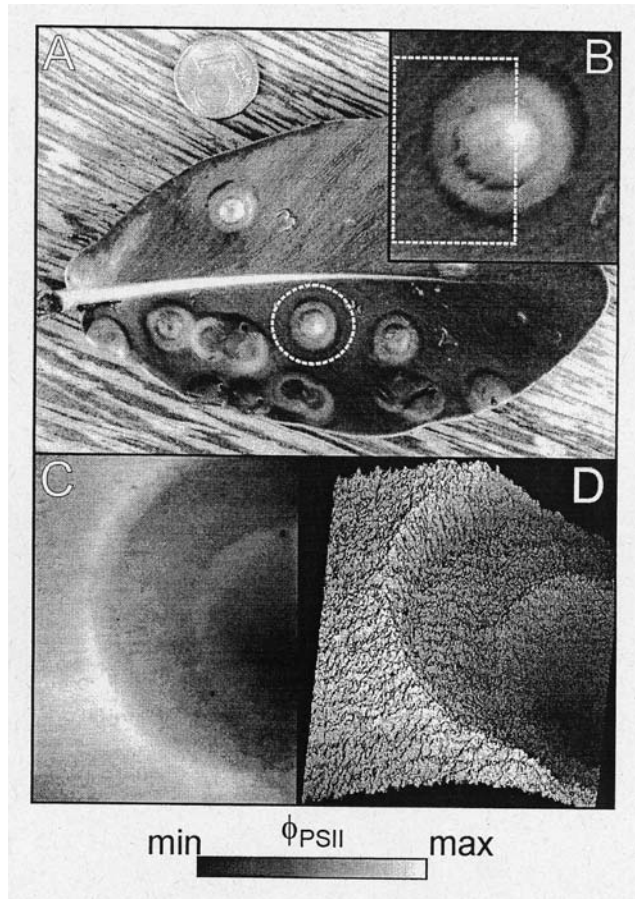


Fig. Syn.2A-C. Gall wasp infected leaves of *Clusia*: A *C. arrudae* Planch. et Triana in the Cerro do Cipó, Brazil (see Sect. 9.4.2.3); B,C *C. aemygdioi* in the Atlantic rain forest, Brazil (see Sect. 9.4.2.10)



Fig. Syn.4A–D. *Clusia* used: A for afforestation of a secondary savanna; B as ornamental tree at a gas station in Costa Rica; C in the city centre of Rio de Janeiro; D near the yacht harbour of Waikiki

ciated in afforestation programmes (Fig. Syn.4A), it is used in horticulture (Sternberg et al. 1987) and is often liked as an ornamental plant in the tropics, be that in the garden of a gas station in Costa Rica (Fig. Syn.4B), in the city centre of Rio de Janeiro (Fig. Syn.4C) or on hotel terraces in Waikiki (Fig. Syn.4D).

References

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