

Infections by pigmented algal endophytes: misuse of concepts and terminology

Infecciones por algas endofíticas: mal uso de conceptos y terminología

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ABSTRACT

Terminology describing intimate relationships between algal endophytes and their algal hosts has been used in a poorly rigorous manner. In this context, concepts are presented which appear important to be considered at the time of classifying such algal relationships. The information presented strongly suggests that the terms endophyte, parasite and pathogen should not be considered interchangeable.

Key words: Endophyte, parasite, pathogen, algae, symbiosis, misuse.

RESUMEN

Los términos que describen las relaciones íntimas establecidas por algas endofíticas con sus algas hospederas han sido usados, hasta ahora, en forma poco rigurosa. En este contexto, se presentan los elementos conceptuales a considerar en el momento de clasificar los distintos tipos de asociaciones íntimas entre algas. Dichos antecedentes indican, además, que términos tales como endófito, parásito y patógeno no deben ser usados como sinónimos.

Palabras claves: Endófito, parásito, patógeno, algas, simbiosis, mal uso.

Intimate associations among algae are quite common in nature, and in this context, numerous species of small filamentous green, brown, and red algae have been reported living deeply embedded within the tissues of larger algal hosts. Because of their peculiar habit, these invasive algae are known as endophytes. The presence of well developed chloroplasts has resulted in the generalized idea of considering these organisms as casual intruders that have little, if any, impact on their hosts. This view has been reinforced by studies where many of these algae have been isolated and grown separated from their hosts (i.e. Boney 1972, Garbary 1979, Correa et al. 1988, Apt 1988). Recent experimental studies, however, have established that a number of endophytic algae induce either degradative or tumoral lesions in their rhodophycean hosts (Correa & McLachlan 1994, Correa et al. 1993, in press). For example, a serious negative effect on the performance of the

red alga *Chondrus crispus* Stackhouse results from degradative lesions caused by *Acrochaete operculata* Correa et Nielsen and *A. heteroclada* Correa et Nielsen (Correa & McLachlan 1992). Similar degradative lesions develop in *Iridaea lamina-rioides* Bory infected by *Endophyton* sp. (Correa et al. in press). In the light of this new evidence, it becomes apparent that the use of the term endophyte results in ambiguities or misleading interpretations when referring to the above associations. The term endophyte describes a spatial relationship between the associates, but it does not convey any meaning on whether the net impact of the association is detrimental, neutral, or beneficial for either partner. More precise terms have been used to describe algal associations, although poor rigorousness in using these terms is evident. For example, using the same type of descriptive information, invasive members of the phaeophycean

genus *Streblonema* Derbes et Solier have been referred to as endophytes (Abbott & Hollenberg 1976), parasites (Setchell & Gardner 1922, Dangeard 1931), and pathogens (Yoshida & Akiyama 1979, Apt 1988). Furthermore, the term symbiosis has been used to describe infections of algae by chlorophycean endophytes (Correa et al. 1988). Thus, my purpose is to review the terms and concepts involved in classifying inter-organismic associations, and discuss them in the context of intimate relationships between algae and their pigmented endophytes. Such analysis is absent from the literature (Andrews 1975, Goff 1983, Correa & Craigie 1991), and I consider it as an important step in unifying criteria for the proper use of concepts and terminology in future studies, particularly those dealing with algal diseases.

Inter-organismic associations have been studied under the umbrella concept of symbiosis. Symbiosis was originally conceptualized by de Bary (1879) as a very broad term, describing the living together of dissimilarly named organisms. In this context, and regardless the potential pathogenicity displayed by some pigmented algal endophytes, classification of the associations established between these organisms and their algal hosts as symbiosis (*sensu de Bary 1879*) is appropriate. A narrower meaning of symbiosis, equated with associations leading to mutual benefit, has been also used by other authors (Lewis 1973, Lewin 1982). Recent authors agree, however, with the broader original concept (Lewis 1973, Starr 1975, Goff 1982a, Smith and Douglas 1987, Douglas and Smith 1989) and some criticize the narrow connotation as an «historical accident» (Ahmadjian and Paracer 1986).

Within a symbiotic association, the effect of one symbiont upon the other may be beneficial, innocuous or harmful. In this context, there has been considerable debate in attempting to clarify the nomenclature used for symbionts inducing negative effects on their hosts. Parasitism, for example, has been used to describe associations where «... at least some harm is predictably caused ...» by the parasite to the host (Begon et al. 1990). A parasite has

also been defined, on physiological basis, as any organism that develops on or within a living host and from which it derives at least part of its nutrition (Hall 1974, Ahmadjian & Paracer 1986, Agrios 1988). No further implications regarding whether such unilateral «feeding» is detrimental, emerge from the latter definition. An integrative view was provided by Crofton (1971 a, b), who considered parasitism as an ecological relationship characterized by 1) a physiological dependence of the parasite on its host; 2) a potential death of the host; 3) the parasite's reproductive potential higher than that of the host; and 4) an overdispersion of the parasite within the host population. The term pathogen, on the other hand, is reserved for those organisms that have the capacity of causing a disease (pathogenicity), regardless of the mechanism utilized. These mechanisms may include nutrient withdrawal, production of toxins, etc., and are the responsible for the symptoms and signs that define a particular disease (Hall 1974, Ahmadjian & Paracer 1986, Agrios 1988). Obviously, a parasite may become pathogen if, for example, nutrient withdrawal results in host impairment.

Within the above conceptual framework, little doubt seems to be left for considering any pigmented algal endophyte as a pathogen, if evidence shows that the presence of these organisms causes disruption or impairment of vital functions in the host. Slower growth, loss of regeneration capacity, and the co-occurrence of severe damage at cellular and tissue levels, are some of the symptoms observed during the infection of algal hosts by algal endophytes (Yoshida & Akiyama 1979, Apt 1988, Correa & McLachlan 1992, 1994, Correa *et al.* 1993), and certainly support the classification of the infecting algae as pathogens.

Considering pigmented algal endophytes as parasites, however, is incorrect owing our incomplete knowledge about nutritional aspects in these associations. Nutritional dependence upon their hosts is a feature included in most definitions of a parasite, however it has not been reported for any pigmented endophyte. In fact, the

establishment of unialgal cultures where these organisms develop and reproduce normally, strongly suggests a nutritional independence from their hosts. Clear conceptual distinctions between parasite and pathogen have been exemplified using fungal-higher plant systems (Hall 1974, Ahmadjian & Paracer 1986), and can also be done using algal systems. Red algal parasites, for example, are characterized by obtaining at least part of their metabolic requirements from their algal host (Goff 1982b, Kremer 1983), although have been rarely reported to cause damage or dysfunction in their partners. For at least two of these parasitic associations, however, experimental evidence has indicated a reduction or cessation of growth of the infected plants (Nonomura 1979, Apt 1984). In the association between *Hypneocolax stellaris* Borgesen and its host *Hypnea musciformis* (Wulfen) Lamouroux, Apt (1984) considered the poor growth caused by the parasite to be a disease, and accordingly, classified the parasite as a pathogen.

Additional aspects should be considered to classify inter-organismic associations and prevent the misuse of the terms parasite and pathogen in algal systems. For example, a particular association can be *obligated* or *facultative* (Starr 1975, Smith & Douglas 1987). A complication in the above dichotomy arises in cases where a given organism grows isolated in laboratory culture, but in nature is found only associated with a specific partner. This led Brian (1966) to differentiate physiological obligation, an absolute dependence on a partner, from ecological obligation, which is the inability of one partner to survive in the natural environment separated from the other. Parasitic red algae, for example, are physiologically obligated symbionts and cannot develop isolated from their hosts (Goff 1982 b). The apparently obligated endophytic habit displayed by some members of *Acrochaete*, *Entocladia*, and *Acrochaetium* is, however, certainly non-physiological, as demonstrated by the ability of numerous isolates to grow and reproduce under diverse abiotic conditions in absence of the host (White & Boney

1969, Boney 1972, Garbary 1979, Correa et al. 1988, Correa & McLachlan 1991, Correa et al. 1993, in press). Instead, there are indications that several pigmented algal endophytes are ecologically obligated symbionts. These include the presence of a very fragile thallus unable to remain attached to any alive or inert surface (Boney 1972, Correa et al. 1988, Correa et al. 1993, in press) and a narrow host-specificity (White & Boney 1969, Garbary 1979, Correa & McLachlan 1991). Furthermore, these organisms have never been reported as free living species.

It is concluded from this analysis that the terms endophyte, parasite and pathogen, including their respective sub-divisions (i.e. obligated and facultative), are well defined types of relationships between two symbionts. In this context, intimate associations between algal partners should be analyzed as any other symbiosis, and by no means the terms endophyte, parasite and pathogen should be considered interchangeable. This precaution is particularly important when reporting on algal diseases, where the lack of basic knowledge tends to facilitate the use of improper language.

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