Chara sp. an Unfamiliar Algal Element in our Biodiversity

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ABSTRACT

Chara, is a freshwater, green algal genus with cosmopolitan distribution, a species of which can be found in abundance in the limestone ponds at Mayo, central Trinidad. The alga, a member of the Charophyta – a group considered to be ancestral to land plants - has many features of interest, among which are a protective jacket around the reproductive organs (a feature of land plants); true oogamous reproduction; a highly differentiated thallus; and the capacity to deposit calcium carbonate in the water in which it grows. It is also known to produce a substance that is toxic to mosquito larvae.

Key words: Charophyta, limestone ponds, Trinidad, biological control, calcium carbonate

INTRODUCTION

The term alga refers to a diverse group of predominantly aquatic, chlorophyll-containing autotrophic organisms which are not necessarily closely related, and is thus polyphyletic. The group was originally placed in the Kingdom Plantae. However, all algal groups - except the green algae - are currently classified as Protoctista - any eukaryotic organism that is not an animal, plant or fungus - because they possess features which are not shared with land plants such as diversity of life cycles, morphology, cellular organisation and accessory pigments present along with chlorophyll. These additional pigments mask the presence of the chlorophyll, rendering the alga brown, yellow/brown or red.

The green algae which include two divisions, Chlorophyta and Charophyta, are now classified with land plants in the Kingdom Plantae or Chlorobionta. They possess features such as tropisms, circadian rhythms, osmoregulation, cell polarity, basic mating types and plant hormones inherited from a eukaryotic ancestor which make them suitable ancestors as land plants (The Green Plant BAC library project 2017). In fact, a group of green freshwater algae (Charophytes) is believed to be the ancestors of land plants, based on evidence gathered from cell ultrastructure, biochemistry and molecular biology of living members. Thus, green algae in particular the Charophytes, of which the genus *Chara* discussed in the article, is an example, are related by common ancestry to land plants. Classification of organisms is in constant flux but the evidence which identifies the relatedness of green algae and land plants is quite strong and well accepted by the scientific community.

While there is a comprehensive record of the marine elements of our algae (Duncan and Lee Lum 2006), the same does not hold for freshwater species, thus very little is known locally of the genus *Chara*, a representative of which is found in the ponds at Mayo , in the limestone area in central Trinidad.

Distribution and habitat of the genus

The genus is reported as occurring from as far north at 69 degrees in Norway and to about 49 degrees south in the Kerguelen Islands (Pal *et al.* 1962) as cited by Sharma (1986).

In Europe, members of the genus are found growing in lakes and ponds in limestone areas, a habitat referred to as H3140, characterised as hard oligotrophic water, in which the concentration of calcium carbonate ($CaCO_3$) is high, making the water very alkaline. Water in which the level of $CaCO_3$ is above 120 mg/L is regarded as being hard. Some species of the genus are found in slow running water while others grow in different habitats, such as *C. hatei* S. C. Dixit, which grows trailing on the soil, *C. nuda* B. S. Pal and *C. grovesii* B. P. Pal, found on mountains, and *C. wallichii* A. Braun, found in plains (Neelesh 2013). The brackish water charophyte *Chara canescens* Loiseleur, widely distributed in the coastal regions of the Northern Hemisphere (Winter and Kirst 1991) is intermediate between the freshwater species *Chara vulgaris* L. which exhibits adaptability to slightly brackish lake water (Kirst *et al.* 1988) and the euryhaline charophytes in terms of salt tolerance (Winter and Kirst 1991). *Chara buckellii* G. O. Allen, a giant-celled alga is found in a salt lake in Saskatchewan (Hoffmann and Bisson 1990).

Locally, *Chara* is found in the limestone ponds at Mayo in central Trinidad, where the water is very alkaline and the level of $CaCO_3$ is of the order of 343mg/L. The plants are often encrusted with $CaCO_3$, which renders them brittle and rough to the feel; the metabolic processes associated with this deposition often give them an unpleasant smell of hydrogen sulphide. On account of the encrustation they are known as stoneworts.

The plants are anchored in the substrate by rhizoids; these bind the soil particles together, stabilising the bottom sediments thereby preventing muddy water. The water is usually very clear (Fig. 1).

Fig. 1. Limestone pond at Mayo, showing growths of *Chara* sp. beneath the surface of the clear water

Structure

The thallus of *Chara* is branched, multicellular and macroscopic. Most species grow to a height of 30cm, but some grow as tall as 1m. However, structurally, there is a main axis, from the base of which fine, branched rhizoids arise. These anchor the thallus in the substratum.

The main axis is differentiated into nodes and internodes. (Fig. 2). The nodes consist of a pair of central cells, surrounded by a ring of 6-20 peripheral cells, from which four types of structures arise: **branches of limited growth** – these are produced in whorls of 6 -20 and are themselves differentiated into nodes and internodes; they are called branches of first order, primary laterals or leaves.; **branches of unlimited growth -** these arise from the axils of the branches of limited growth hence they are called auxiliary branches or long laterals. These may produce branches of limited growth; **stipulodes** – these are short, oval, pointed, single-celled structures (akin to leaves) produced from the basal node of the branches of limited growth, and **cortex-** defined later**.**

The internode consists of a single, much-elongated cell. In some species this cell may be surrounded by a layer of cells called the cortex; such species are corticate species. The cortex consists of vertically elongated, narrow cells. The upper half of each internodal cell is covered by corticating filaments known as descending filaments, developed from the peripheral cells of the upper node. The lower half is covered by filaments developed from the lower peripheral cells of the node; these are known as ascending filaments. The two meet at the middle of internode (Fig. 3).

Reproduction

Both asexual (without nuclear fusion) and sexual (with fusion of nuclei) reproduction are recognised in species of the genus.

Fig. 2. Terminal portion of main axis, a – node, b- branch of unlimited growth, c – branch of limited growth (leaf), d- internode

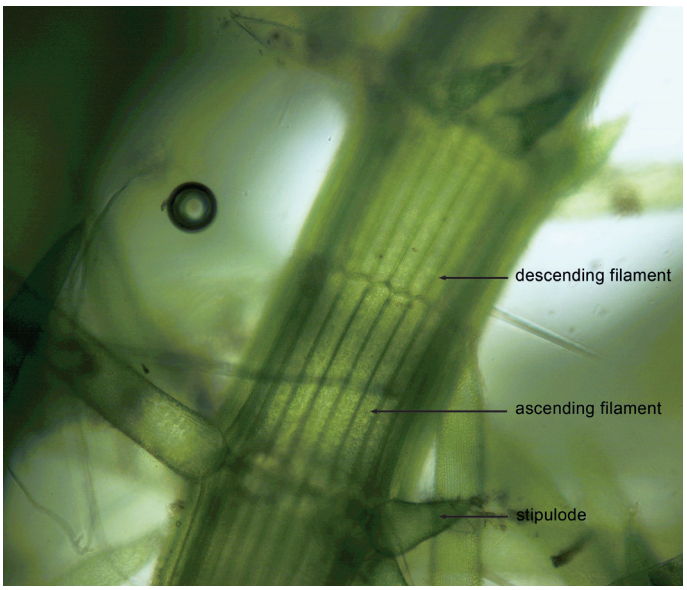

Fig. 3. An internode above and below which stipulodes are seen; ascending and descending corticating filaments are also seen.

Asexual reproduction is purely vegetative. Two forms are recognised: (a) the production of oval, tube-like structures, known as bulbils, on the rhizoids and lower nodes of the main axis, which on detachment, germinate to produce new thalli; and (b) in some species the production of multicellular, star-shaped aggregates of cells filled with starch grains, known as amylum stars, on the lower nodes of the main axis. When they become detached, they develop into new thalli.

Sexual reproduction is recognised in all species of the genus. Two kinds of gametangia are produced, an oogonium (female) – referred to as the nucule and an antheridium (male) referred to as the globule. Both nucule (Fig. 4 left) and globule (Fig. 4 right) are highly differentiated structures.

The globule is the earlier of the two to develop. It is initiated by an adaxial (near to the main axis) peripheral cell of the basal node of a primary branch and is surrounded by a few stipulodes. It is positioned opposite to the descending tube cells of the lower internode. A sterile jacket of cells referred to as the shield is the outermost layer of the organ, and surrounds the numerous sperm cells or male gametes. A sterile jacket around the sex organs is not seen in other algae but is a typical feature of land plants for protection of the gametes against desiccation. The nucule is similarly produced from an adaxial peripheral cell on the basal node of a branch and is opposite to the ascending tube cells of the upper internode. In essence it consists of a central, large ovum (egg), surrounded by long, tubular, sterile cells known as tube cells, which are spirally coiled around the ovum, to form the protective jacket. The terminal portions of the tube cells are cut off by a cell wall; these tips form a crown at the top of the nucule, known as the corona.

When the calcium carbonate encrustation is removed with dilute hydrochloric acid and the chlorophyll bleached, the structure of the sex organs is seen more clearly (Fig. 5).

At maturity of the nucule, the spiral tube cells separate from each other, making a space for entry of the sperm, one of which enters the ovum and effects fertilisation (Kumar and Singh 1979).

In some species, both sex organs are produced on the same plant, these are said to be monoecious; in other species, plants of different sexes are produced. These are said to be dioecious.

Two species of the genus appear to grow in the ponds at Mayo. This observation is based on the facts that: (a) in one, the branching is more profuse than in the other and the internodes are shorter, making it more bushy that the other (Fig. 6); (b) there is a difference between the two in the shape of the units of the corona – in one they are acutely triangular, in the other the upper portions of the sides are concave; and the angle of the coils of tube cells is different in the two (Figs. 7); and (c) one species is monoecious (Fig. 8 left), the other is dioecious (Fig. 8 right).

Fig. 4. Nucule on upper side of node (left) and Globule, on lower side of node (right)

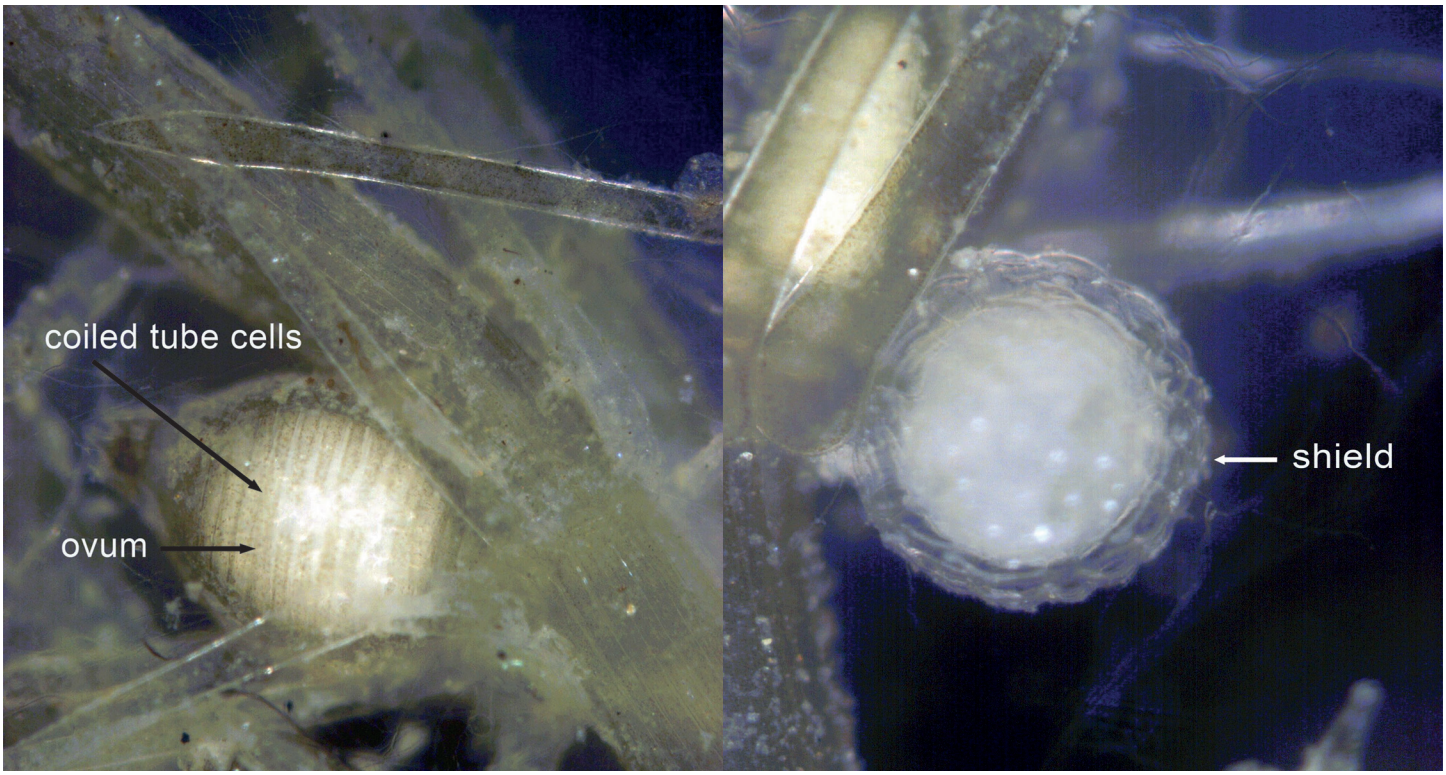

Fig. 5. *Chara* sp sex organs; female nucule (left), and male globule (right), cleared of calcium carbonate encrustation and chlorophyll to show sex organs in greater detail.

Fig. 6. Sparsely branched (left); richly branched (bushy) right

Interesting facts about the genus

Lucus (1982) demonstrated that exogenous bicarbonate HCO_3- dissolved in the water entered the internodal cells of *C. corallina* Klein ex C. L. Willdenow across the plasmalemma. In the cell carbon dioxide is acquired from the bicarbonate for photosynthesis and hydroxyl (OH−) ions are released into the water which increases the water pH and results in the remaining bicarbonates (HCO3−) combining with dissolved calcium ions (Ca2+), forming calcite crystals (Pelechaty *et al.* 2013). The thallus of *Chara* is often encrusted with calcium carbonate as a result of these deposits (Fig. 8b.) Those with a single internodal cell (which can be up to 2cm in length) may show discrete 2-3mm acid and

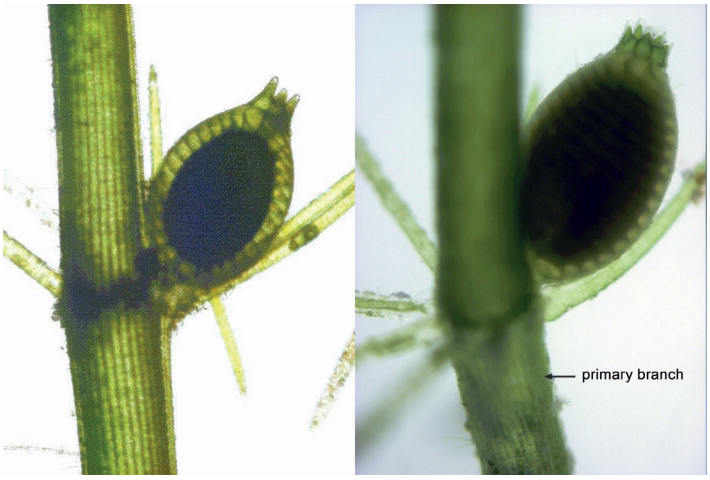

Fig. 7. Corona with cone-shaped units (left); corona with pen nib shaped units (right)

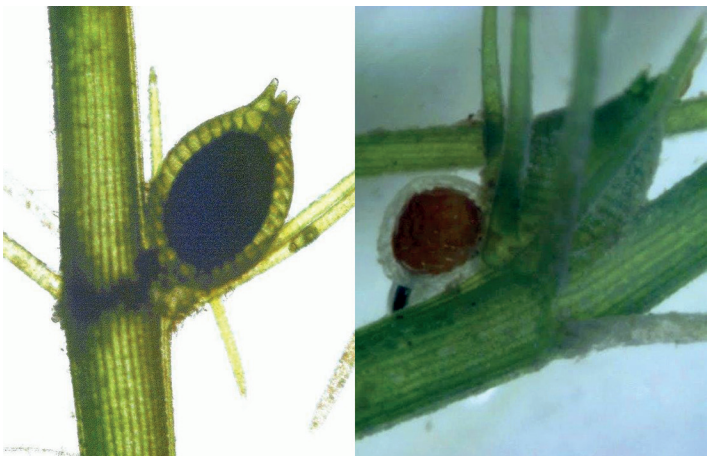

Fig. 8. monoecious species (left), dioecious species (right)

alkaline bands, Such "giant algal cells" were also used in pioneering studies on plant ionic balance across cell membranes providing fundamental insights into cellular electrical and ionic interactions which may have applicability to land plant cells.

The phenomenon of allelopathy is also observed in *Chara* spp. with several reports reviewed by (Wium-Andersen *et al.*1982) indicating the absence of phytoplankton epiphytes on stands of *Chara* spp. growing in both freshwater lakes and in brackish waters. Wium-Anderson *et al.* 1982 credits this observation to the adverse effect of sulphur compounds produced by *Chara vulgaris* L. on photosynthesis in epiphytes and suggests a use for these extracts in reducing growth of phytoplankton.

Matheson and Hinman (1928) made mention of an observation of Caballero's on the larvicidal properties of *Chara* spp. He pointed out that in a spring-fed pond in New York in which *Chara globularis* Thuiller (synonym *Chara fragilis* Desvaux) grew densely, no mosquito larvae were present.

In an experiment in which large, water-filled wooden buckets were placed in the ground, it was found that the mosquito *Culex territans* WIk bred in large numbers, but in similar buckets in which *C. vulgaris* was grown, few eggs were laid and the resulting larvae all died (Matheson and Hinman 1928). Jacobsen and Pedersen (1983) found in an extract from *C. globularis* Thuiller, a fraction with insecticidal properties similar to those of the structurally related nereistoxin.

ACKNOWLEDGEMENTS

The authors acknowledge with thanks the assistance of Mr Terry Sampson with macrophotography, Ms. Sarah Evelyn with microphotography and Mr Christopher Frost for facilitating visits to the site.

Glossary

Allelopathy - the adverse effect of one organism on another expedited through chemical agents.

Asexual reproduction - the formation of new individuals from the cell(s) of a single parent and does not involve nuclear fusion

Axil – in an alga or plant, the angle between the main axis and any lateral structure, such as branch or leaf.

Circadian rhythm – a physical, mental or physiological change that follows a roughly 24-hour cycle, responding primarily to light and darkness

Dioecious - having the male and female organs on separate and distinct individuals.

Eukaryotic - any organism having as its fundamental structural unit, a cell that contains specialised organelles in the cytoplasm, such as a nucleus and mitochondria

Gamete - a cell that fuses with another cell during fertilisation in organisms that reproduce sexually.

Monoecious - having both male and female organs in the same individual.

Oligotrophic – characterised by a low accumulation of dissolved nutrient salts, supporting but a sparse growth of algae and other organisms, especially in the case of lakes

Osmoregulation - maintenance by an organism of an internal balance between water and dissolved materials

Polyphyletic - developed from more than one ancestral type, as a group of animals or plants

Rhizoid - protuberances that extend from the lower epidermal cells of bryophytes and algae. They are similar in function and in some respects structure to roots.

Sexual reproduction- the formation of a new individual following the union of two gametes.

Stonewort - a plant-like group of green algae constituting the class Charophyceae, having a jointed body frequently encrusted with calcium carbonate

Thallus (pl**. thalli**) **-** the body of a plant that does not have leaves, stems and roots.

Tropism - a growth movement the direction of which is determined by the direction from which the stimulus strikes the plant.

Whorl - an arrangement of sepals, petals, leaves, stipules or branches that radiate from a single position around the stem.

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