

## **A taxonomic study of the genus *Closterium* Nitzsch ex Ralfs (Zygnematophyceae, Streptophyta) in temporary ponds in the Burkina Faso, West Africa**

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**Abstract** – The number of *Closterium* species known from the Burkina Faso is small. The present study aims to contribute to the knowledge of species of this genus in Burkina Faso by means of an investigation of temporary ponds. The study of *Closterium* in ponds was conducted in the central and the eastern parts of the country, during the rainy seasons of 2007 and 2008. Samples were collected and preserved with formalin. Aliquots of the samples were examined and illustrations made with a light microscope equipped with a drawing tube and a camera. Identifications of species were made with the use of standard works. In total, twenty-six taxa of *Closterium* were identified and described. Among them, twenty-four have already been reported from Africa and nineteen are cosmopolitan. Eighteen species (62%) are new for the country. The number of species reported shows that *Closterium* could be considered as a diverse genus in temporary ponds. Some species are either neutrophiles or alkaliphiles but many of them are neutrophiles as well as alkaliphiles.

**African ponds / *Closterium* / desmids / phytoplankton / taxonomy**

**Résumé** – Etude taxinomique du genre *Closterium* Nitzsch ex Ralfs (Zygnematophyceae, Streptophyta) dans des étangs temporaires (Burkina Faso, Afrique de l'Ouest). Au Burkina Faso, le nombre d'espèces connues de *Closterium* est petit. Cette étude a pour objectif de contribuer à la connaissance des espèces de ce genre dans le Burkina Faso à travers une investigation dans des étangs temporaires. L'étude a été conduite dans la partie centrale et la partie est du pays au cours des saisons pluvieuses de 2007 et 2008. Les échantillons sont collectés et conservés dans le formol. Les aliquotes ont été examinées à l'aide d'un microscope optique équipé d'un tube à dessins et d'un appareil photo. L'identification des espèces a été effectuée sur la base d'ouvrages classiques. Au total, vingt six taxons de *Closterium* sont identifiés et décrits. Parmi eux, vingt quatre sont déjà rencontrés en Afrique et dix neuf cosmopolites. Dix huit espèces (62 %) sont nouvelles pour le pays. Le nombre d'espèces rencontrées montre que le genre *Closterium* peut être considéré comme diversifié dans les étangs temporaires. Des espèces sont soit neutrophiles soit alcalinophiles mais beaucoup sont aussi bien neutrophiles qu'alcalinophiles.

***Closterium* / desmidiées / étangs africains / phytoplankton / taxinomie**

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## INTRODUCTION

The algal habitats of Burkina Faso are many and diverse. Ponds, one of the smallest types of standing waterbodies, are abundant in the central and eastern region of this country. During the rainy season, the savannah in these regions is dotted with numerous temporary ponds. Water from these ponds is used by populations and cattle especially for consumption. In this way, they are of a socio-economical interest for the society in these regions of Burkina Faso.

Despite their ephemeral characteristics, temporary ponds can be densely populated by micro-algae, at least for certain time during the growing season. There are still only a few studies with regard to the algae of the temporary waters in West Africa. However, studies of ponds in Côte d'Ivoire (Bourrelly, 1961) and pools in Sierra Leone (Ricci *et al.*, 1990) have been published.

Many of the freshwater habitats in Burkina Faso remain unexplored. Previous works (e.g. Zongo & Guinko, 1999; Zongo *et al.*, 2008) focused on the studies of micro-algae from reservoirs, canals and rivers in this country. The number of species of *Closterium* known from this country is small. The genus *Closterium* is one of the important genera of desmids in West African freshwater ecosystems (Bourrelly, 1975; Gerrath & Denny, 1988 and Gerrath & John, 1988).

The present study, which aims at partly closing this gap, deals with the species of *Closterium* (Zygnematophyceae, Streptophyta) in temporary ponds in the central and eastern parts of Burkina Faso.

## MATERIAL AND METHODS

### Study areas

Investigations were conducted in the central and the eastern parts of Burkina Faso (West Africa). The study area lies between the latitudes 10° 56' 3" and 12° 47' 10" North and the longitudes 1° 6' 40" West and 1° 24' 23" East (Fig. 1) and belongs to the sudanian zone (tropical type). Two seasons characterize these areas: a rainy season from June to September with a maximum rainfall in August and a dry season from October to the end of May. March, April and May are the warmest months of the year when temperature can reach 40°C while December and January are the coldest ones with an average of about 20°C.

A representative number of ponds in each region (30 in the central and 31 in the eastern part) has been chosen for the collection of samples of micro-algae. In total, sixty-one (61) temporary ponds of the two regions have been sampled. Collection of samples was done two times during the rainy seasons (in August and September) of 2007 and 2008. Table 1 shows mean values of physico-chemical parameters during the periods of study. Water in ponds was covered or not by aquatic plants.

### Collection of samples and species identification

Collections were made in the open water with a tube of 120 ml. The tube catches were transferred into collection bottles and immediately preserved with 5% formalin.

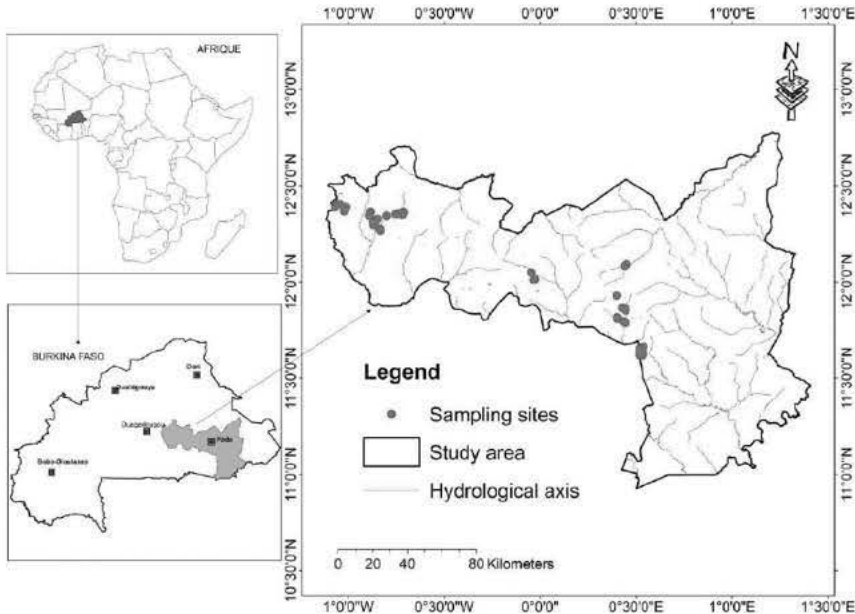


Fig. 1 – Map of the Burkina Faso showing the sampling stations

Aliquots of the samples were examined, photographed and drawn using an Olympus CH20 Microscope equipped with a camera (Kodak EasyShare C613) and a drawing tube. Identifications of species were made by using standard works, especially the following: Bourrelly, 1975, 1990; Bourrelly & Couté, 1986; Compère, 1977, 1980, 1991; D Hollander & Caljon, 1980; John *et al.*, 2002; Ouattara *et al.*, 2000; Prescott *et al.*, 1975; Wehr & Sheath, 2003.

## RESULTS

Twenty-six species of *Closterium* were found in temporary ponds during the investigations. All of them are described and illustrated below. Species new to Burkina Faso are marked with an asterisk (\*).

### *Closterium acerosum* Ehrenberg *ex* Ralfs *var. minus* Hantzsch

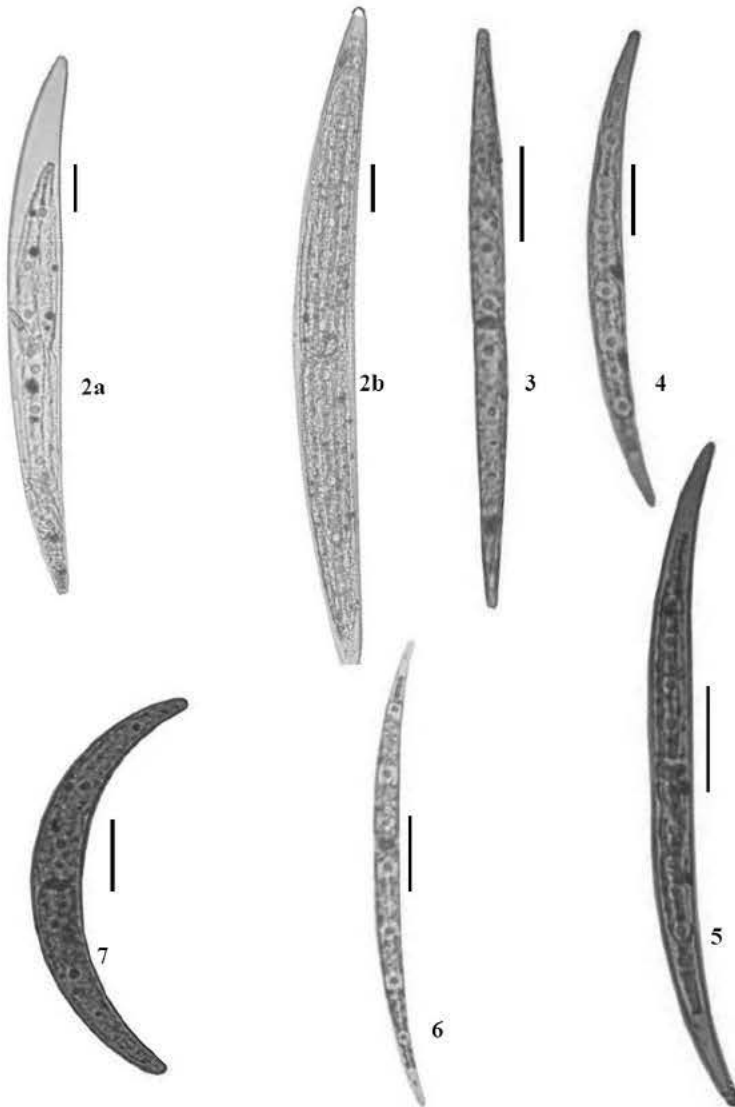
Fig. 2

Cells 9.7 to 10.5 times longer than broad, slightly curved to almost straight, narrowly fusiform, the inner margin straight or slightly convex, with a curvature of 20-30, gradually tapering to the poles which are narrow and truncately rounded, often angularly thickened. Chloroplast with 3-7 longitudinal ridges and with 5-9 axial pyrenoids. L. 285-328.1  $\mu\text{m}$ , W. 29.7-31.2  $\mu\text{m}$ . Distribution: Cosmopolitan. In Burkina Faso: PC 1, 2, 5, 6, 7, 9, 11, 12, 13, 25; PE 1, 2, 8, 13, 14, 15, 17, 18, 22, 23, 27, 29.

### \**Closterium acutum* Brébisson *ex* Ralfs *var. latius* Grönblad

Fig. 3

Cells straight over their entire length, 14.3-15.7 times longer than broad; inner margin not tumid, gradually attenuated to acutely rounded poles; wall



Figs 2-7. 2a, b. *Closterium acerosum* var. *minus*. 3. *Closterium acutum* var. *latius*. 4. *Closterium calosporum* var. *brasiliense*. 5. *Closterium calosporum* var. *majus*. 6. *Closterium cornu*. 7. *Closterium cynthia*. Scale bars represent 25  $\mu\text{m}$  for all figures.

smooth and colorless; chloroplast with 4-5 axial pyrenoids. L. 134.4-146.9  $\mu\text{m}$ ; W. 9.4  $\mu\text{m}$ . Distribution: Africa, Europe. In Burkina Faso: PC 8, 9; PE 21, 29.

\**Closterium calosporum* Wittrock var. *brasiliense* Børgesen

**Fig. 4**

Cells 12-15.2 times longer than broad, slightly curved; curvature 28-30; dorsal wall convex, poles narrowed and rounded; chloroplast with 3 longitudinal

ridges and 5 pyrenoids. L. 112.5-118.7  $\mu\text{m}$ ; W. 7.8-9.4  $\mu\text{m}$ . Distribution: Cosmopolitan. In Burkina Faso: PC 2, 4, PC 8, 28; PE 8, 12, 23, 27, 31.

**\**Closterium calosporum* Wittrock var. *majus* W. et G.S. West** **Fig. 5**

Cell 13.7 times longer than broad, moderately curved, curvature 20; ventral margin slightly concave, not inflated in the midregion, sometimes straight, gradually attenuated to broadly truncate poles which often have an inner thickening of the wall. Chloroplast with 3 longitudinal ridges and with 6 pyrenoids. L. 150  $\mu\text{m}$ ; W. 10.9  $\mu\text{m}$ . Distribution: Subcosmopolitan. In Burkina Faso: PC 1, 6, 8, 9, 13, 18, 25, 26; PE 1, 7, 13, 17, 21, 27, 28, 30, 31.

***Closterium cornu* Ralfs ex Ralfs** **Fig. 6**

Cell 14.5 times longer than broad, slightly curved, curvature 22, not inflated in midregion, ventral margin straight, dorsal margin convex; gradually narrowing towards truncate poles, wall smooth, colorless; chloroplast with 4 pyrenoids in series. L. 113.3  $\mu\text{m}$ ; W. 7.8  $\mu\text{m}$ . Distribution: Cosmopolitan. In Burkina Faso: PC 4; PE 8, 23.

**\**Closterium cynthia* De Notaris** **Fig. 7**

Cells 5.6 to 8 times longer than broad, strongly curved, curvature 175, ventral wall concave, straight or slightly inflated in the midregion, gradually attenuated to the apical region, the poles sharply rounded; wall smooth and colorless to brownish; chloroplast with 2-3 pyrenoids. L. 87.5-125  $\mu\text{m}$ ; W. 15.6  $\mu\text{m}$ . Distribution: Cosmopolitan. In Burkina Faso: PC 2, 10, 17, 18, 21, 24.

***Closterium ehrenbergii* Meneghini ex Ralfs var. *ehrenbergii*** **Fig. 8**

Cells 5.2 to 6 times longer than broad, stout, moderately curved, curvature 130 to 140, the ventral margin concave but inflated in the midregion, dorsal region strongly convex, gradually attenuated to obtusely rounded poles; wall smooth and colorless, without girdle bands, chloroplast with 3-7 longitudinal ridges and with numerous scattered pyrenoids. L. 406.2-468.7  $\mu\text{m}$ ; W. 78.12  $\mu\text{m}$ . Distribution: Cosmopolitan. In Burkina Faso: PC 2, 4, 9, 13, 15, 17, 25; PE 1, 7, 10, 13, 14, 15, 18, 22, 27.

**\**Closterium ehrenbergii* Meneghini ex Ralfs var. *atumidum* Grönblad** **Fig. 9**

Cell more elongated than the former taxon, 7.5 times longer than broad, strongly curved, curvature 132, not inflated in the midregion; wall colorless to brownish; wall finely striated. Chloroplast with 6 ridges and with numerous scattered pyrenoids. L. 375  $\mu\text{m}$ ; W. 50  $\mu\text{m}$ . Variety reported by Bourrelly & Couté (1986) from Ile Maurice. In Burkina Faso: PE 21.

**\**Closterium ehrenbergii* Meneghini ex Ralfs var. *malinvernianum* (De Notaris) Rabenhorst** **Fig. 10**

Cells 4 to 6 times longer than broad, stout, moderately curved, curvature 133 to 135, the ventral margin concave but inflated in the midregion, dorsal region strongly convex, gradually attenuated to obtusely rounded poles; wall brownish and finely striate, finely and irregularly punctuate. Chloroplast with 3 longitudinal ridges, and with numerous, scattered pyrenoids. L. 221.9-268.7  $\mu\text{m}$ ; W. 40.6-46.9  $\mu\text{m}$ . Distribution: Cosmopolitan. In Burkina Faso: PE 10, 14, 16, 27.

**\**Closterium gracile* Brébisson ex Ralfs****Fig. 11**

Cells 16 times longer than broad, slender, almost straight for more than one-half of the length, curvature 18, margins parallel, gradually narrowed and gracefully curved toward the apical region, poles obtuse; chloroplast with 5 pyrenoids. L. 125 µm; W. 7.8 µm. Distribution: cosmopolitan. In Burkina Faso: PC 8, 27, 29; PE 1.

**\**Closterium lanceolatum* Kützing ex Ralfs****Fig. 12**

Cell 5.8 times longer than broad, straight; margins straight, midregion convex; wall smooth, colorless; chloroplast with about 12 ridges and with 5 axial pyrenoids. L. 397.7 µm; W. 68.2 µm. Distribution: Cosmopolitan. In Burkina Faso: PC 3, 9, 10, 13, 25, 27; PE 12, 13, 26.

***Closterium leibleinii* Kützing ex Ralfs****Fig. 13**

Cells 6 to 6.4 times longer than broad, strongly curved, curvature 120-131, inflated in the midregion, gradually attenuated to acutely rounded poles; wall smooth and colorless to somewhat brownish; chloroplast with 3 to 6 longitudinal ridges and with 3-9 pyrenoids. L. 100-190.6 µm; W. 15.6 – 31.2 µm. Distribution: Cosmopolitan. In Burkina Faso: PE 22, 31.

**\**Closterium lineatum* Ralfs****Fig. 14**

Cells 17.5 to 20.2 times longer than broad, slender, moderately curved, curvature 30, midregion straight with parallel margins; apical region symmetrically curved, gradually attenuated to broadly truncated poles. Chloroplast with 15-19 pyrenoids. L. 315.6-327.6 µm; W. 15.6-18.7 µm. Distribution: Cosmopolitan. In Burkina Faso: PC 8, 18, 22, 24, 27, 29. PE 1, 9, 14, 20, 21, 22.

**\**Closterium littorale* Gay var. *crassum* W. et G.S. West****Fig. 15**

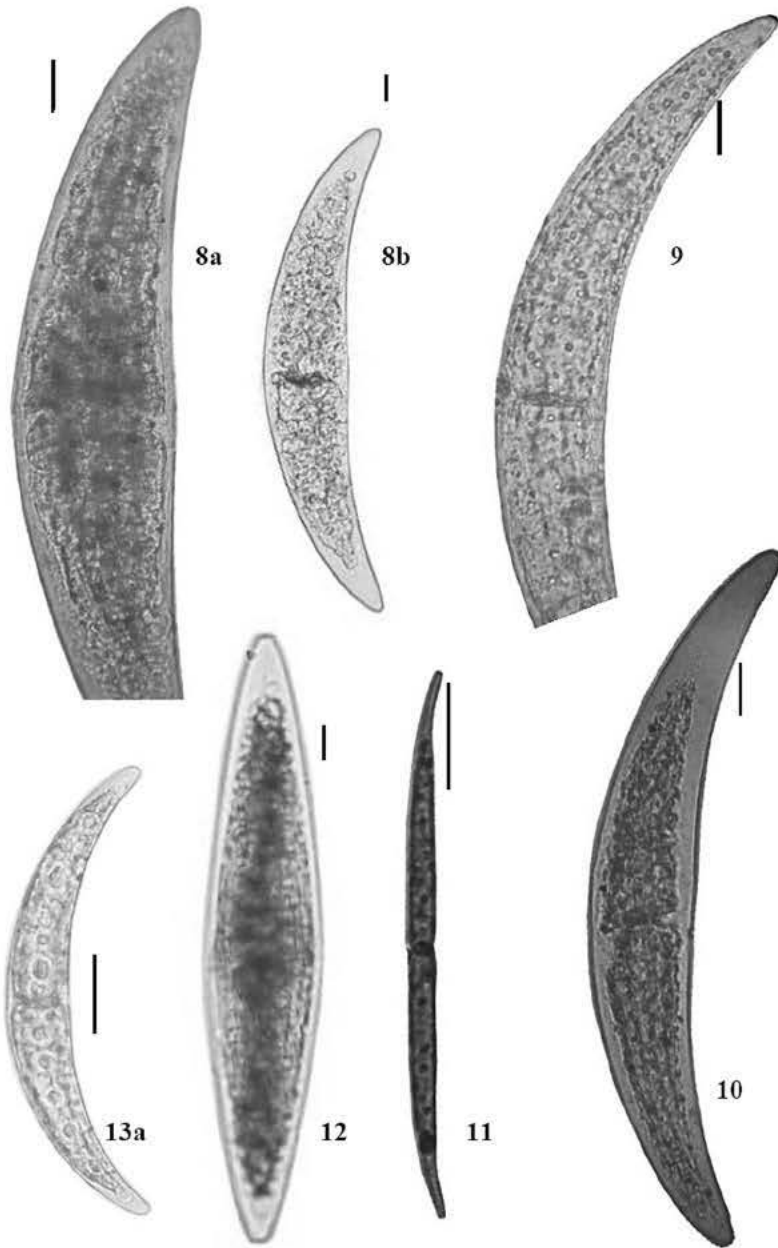
Cells 5.6 times longer than broad; slightly and symmetrically curved, curvature 36; wall smooth and colourless; chloroplast with 2 longitudinal bands and with 3 pyrenoids. L. 208.4 µm; W. 37.5 µm. Distribution: Cosmopolitan. In Burkina Faso: PC 5, 21, 26; PE 3, 14, 15, 17.

**\**Closterium macilentum* Brébisson****Fig. 16**

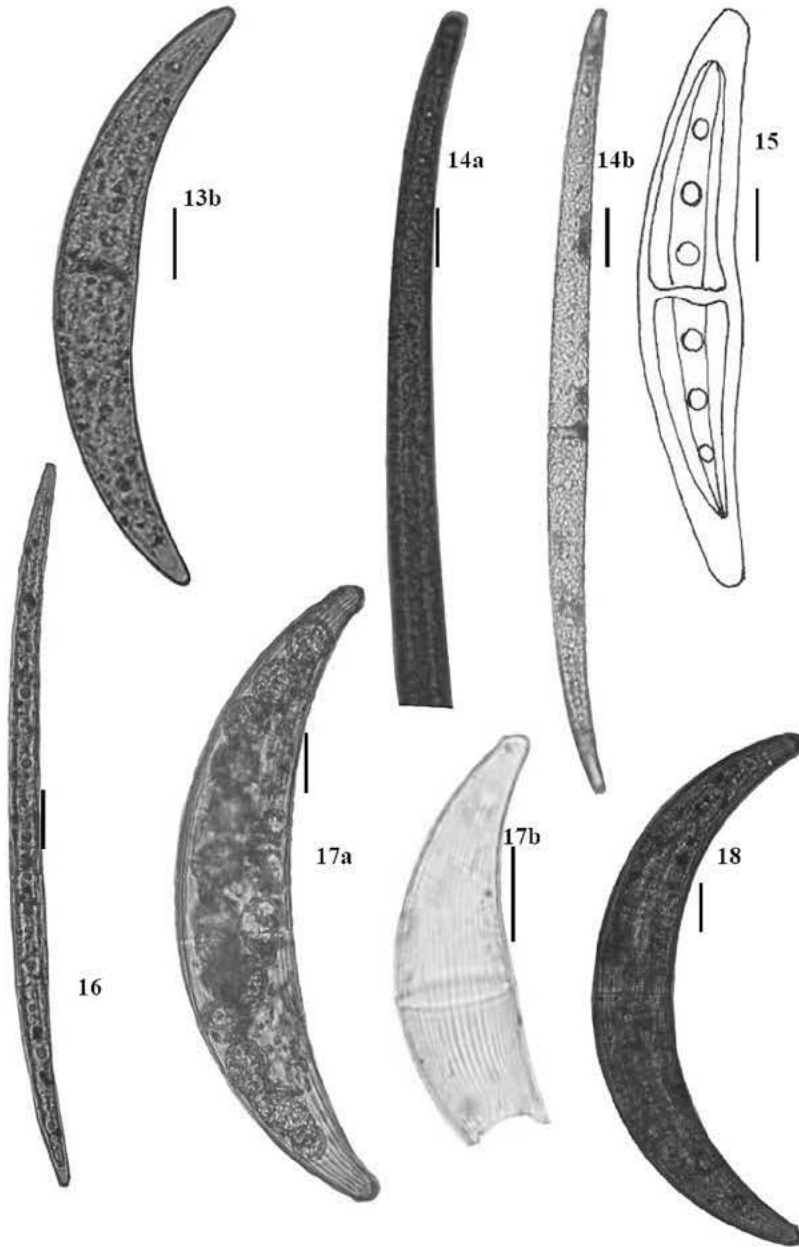
Cell 19.4 times longer than broad, slender, moderately curved, curvature 30-50, midregion straight with parallel margins; apical region symmetrically curved, gradually attenuated to broadly truncated poles. Chloroplast with 9-10 pyrenoids. L. 303 µm; W. 15.6 µm. Distribution: Africa, Europe, East India, Quebec and South America. In Burkina Faso: PC 9, 26.

**\**Closterium malmei* Borge var. *malmei*****Fig. 17**

Cells 5.3 to 7.2 times longer than broad, strongly curved, curvature 109 to 117, not inflated in the midregion; wall colorless to reddish; wall with longitudinal striate; poles capitate with an inner thickening of the wall; chloroplast with 9 axial pyrenoids. L. 250-406.2 µm; W. 46.9-56.2 µm. Distribution: Africa (Côte d'Ivoire by Bourrelly 1961), South America. In Burkina Faso: PC 13, 18, 23, 25. PE 14, 15, 16, 17, 21, 27, 30.



Figs 8-13a. **8a, b.** *Closterium ehrenbergii* var. *ehrenbergii*. **9.** *Closterium ehrenbergii* var. *atumidum*. **10.** *Closterium ehrenbergii* var. *malinvernianum*. **11.** *Closterium gracile*. **12.** *Closterium lanceolatum*. **13a.** *Closterium leibleinii*. Scale bars represent 25  $\mu\text{m}$  for all figures.



Figs 13b-18. 13b. *Closterium leibleinii*. 14a, b. *Closterium lineatum*. 15. *Closterium littorale* var. *crassum*. 16. *Closterium macilentum*. 17a, b. *Closterium malmei* var. *malmei*. 18. *Closterium malmei* var. *semicirculare*. Scale bars represent 25  $\mu\text{m}$  for all figures.



**\**Closterium malmei* Borge var. *semicirculare* Borge** **Fig. 18**

Cell 6.3 times longer than broad, somewhat more slender than the nominate variety and more strongly curved (almost semi-circular in outline), curvature 180, not inflated in the midregion; poles capitate sometimes with an inner thickening of the wall; wall colorless to reddish; wall 6-7 costae and finely striated; chloroplast with 10 axial pyrenoids. L. 256.2; W. 40.6  $\mu\text{m}$ . Distribution: South and North America. In Burkina Faso: PE 21, 28, 29.

***Closterium praelongum* Brébisson var. *praelongum*** **Fig. 19**

Cell 29.3 times longer than broad, slender, moderately curved, curvature 16; margins parallel in the midregion, uniformly attenuated to the somewhat recurved apical region, poles truncate; wall colorless to brown; weakly striated; chloroplast with 2-3 longitudinal ridges and with 8-9 pyrenoids. L. 275  $\mu\text{m}$ ; W. 9.4  $\mu\text{m}$ . Distribution: Cosmopolitan. In Burkina Faso: PC 8.

***Closterium praelongum* Brébisson var. *brevius* Nordstedt** **Fig. 20**

Cells 12-16.3 times longer than broad; margins parallel in the midregion, recurved in the apical region; curvature 18; chloroplast with 3-4 longitudinal ridges and with 8-10 pyrenoids. L. 187.5 – 306.2  $\mu\text{m}$ ; W. 15.6-18.7  $\mu\text{m}$ . Distribution: Cosmopolitan. In Burkina Faso: PC 2, 10; PE 13.

***Closterium pseudolunula* Borge** **Fig. 21**

Cell 6.4 times longer than broad; scarcely curved, curvature 22; the dorsal margin convex, the ventral margin straight or slightly concave; wall smooth, colorless to yellowish-brown; apices truncately rounded; chloroplast with 4 longitudinal ridges and with 5 axial pyrenoids. L. 193.4  $\mu\text{m}$ ; W. 30  $\mu\text{m}$ . Distribution: Cosmopolitan. In Burkina Faso: PC 6, 19, 23, 26, 29.

***Closterium ralfsii* Brébisson ex Ralfs var. *hybridum* Rabenhorst** **Fig. 22**

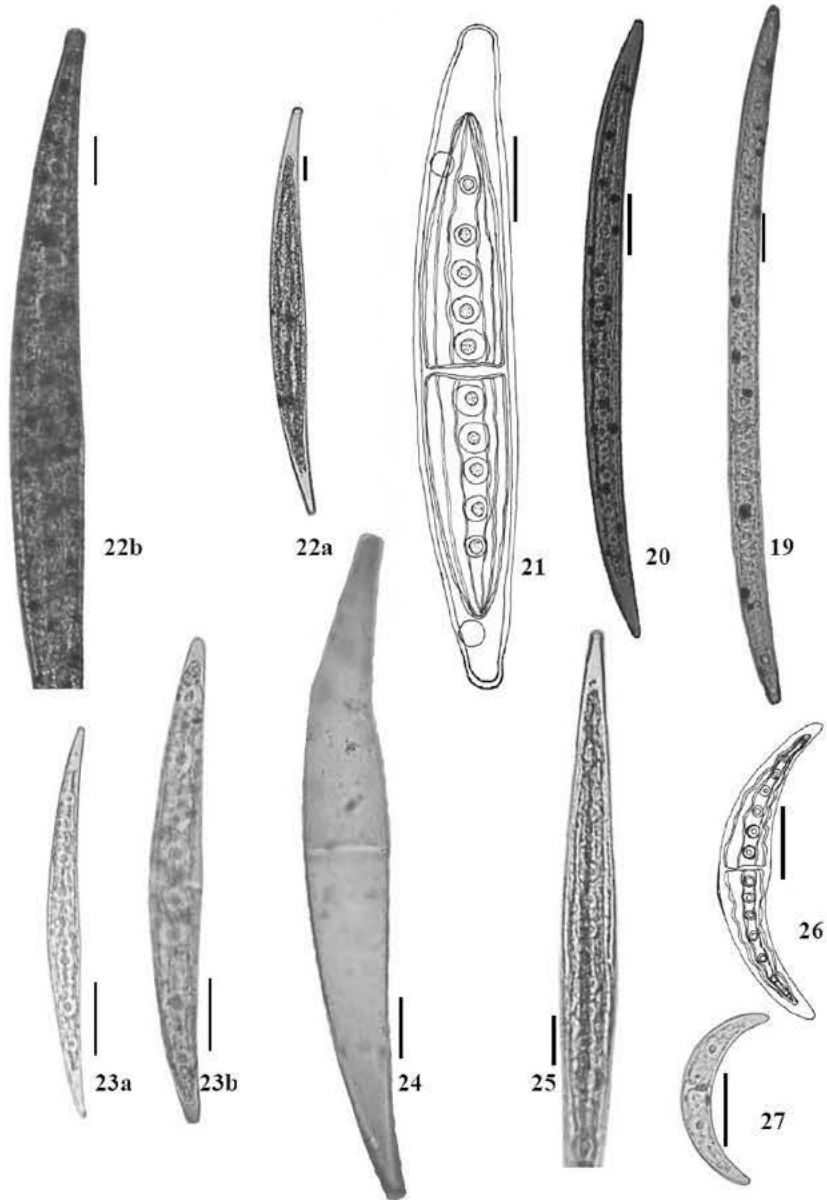
Cells 11.5-13.2 times longer than broad, slender, midregion inflated, curvature 23 to 28; apical region narrowly extended; chloroplast with 3 longitudinal ridges and with 9-15 axial pyrenoids. L. 331.2-425  $\mu\text{m}$ , W. 25-37.5  $\mu\text{m}$ . Distribution: Cosmopolitan. In Burkina Faso: PC 1, 5, 25, 26, 27; PE 1, 7, 13, 16.

**\**Closterium strigosum* Brébisson** **Fig. 23**

Cells 9-11 times longer than broad, slender, slightly curved, curvature 25; not inflated in the midregion, narrowed gradually toward the apical region, poles very narrowly rounded; chloroplast with 2-7 longitudinal ridges and with 5-9 axial pyrenoids. L. 137.5-256.2  $\mu\text{m}$ ; W. 12.5-28.1  $\mu\text{m}$ . Distribution: Cosmopolitan. In Burkina Faso: PC 1, 2, 3, 7, 8, 9, 11, 13, 15, 16, 27; PE 1, 7, 13, 15, 17, 21, 23, 24, 26, 28.

**\**Closterium striolatum* Ehrenberg ex Ralfs** **Fig. 24**

Cell 7.6 times longer than broad, slightly curved, curvature 27; midregion slightly inflated and gradually attenuated toward the apical region which is somewhat incurved; wall finely striate. Chloroplast not visible in our specimen. L. 262.5  $\mu\text{m}$ ; W. 34.4  $\mu\text{m}$ . Distribution: Europe, Asia, Australia, New Zealand, Africa. In Burkina Faso: PC 7, 8, 18, 26.



Figs 19-27. 19. *Closterium praelongum* var. *praelongum*. 20. *Closterium praelongum* var. *brevius*. 21. *Closterium pseudolunula*. 22a, b. *Closterium ralfsii* var. *hybridum*. 23a, b. *Closterium strigosum*. 24. *Closterium striolatum*. 25. *Closterium subfusiforme*. 26. *Closterium tumidulum*. 27. *Closterium venus*. Scale bars represent 25  $\mu$ m for all figures.

**\**Closterium subfusiforme* Messikommer****Fig. 25**

Cell 12.1 times longer than broad, straight and fusiform, equally convex on each margin; gradually tapered to truncate poles; cell wall smooth, without bands; chloroplast with 3 longitudinal ridges and 7-8 axial pyrenoids. L. 359.4  $\mu\text{m}$ ; W. 29.7  $\mu\text{m}$ . Distribution: Switzerland, Korea. In Burkina Faso: PC 2.

***Closterium tumidulum* Gay****Fig. 26**

Cell 5.7 times longer than broad, strongly curved, curvature 115; dorsal wall strongly curved, ventral margin inflated in the midregion, poles acute; wall smooth, colorless; chloroplast with 4 longitudinal ridges and with 7 pyrenoids. L. 110  $\mu\text{m}$ ; W. 19.4  $\mu\text{m}$ . Distribution: Cosmopolitan. In Burkina Faso: PC 23; PE 15, 16, 17.

***Closterium venus* Kützing ex Ralfs****Fig. 27**

Cell 6 times longer than broad, strongly curved with a curvature of 135; dorsal margin convex, the ventral concave, not inflated in the midregion, gradually attenuated toward the apical region, poles acutely rounded; wall colorless to somewhat brownish, smooth; chloroplast with a longitudinal ridge and with 1 to 2 pyrenoids. L. 56.2  $\mu\text{m}$ ; W. 9.4  $\mu\text{m}$ . Distribution: Cosmopolitan. In Burkina Faso: PC 8, 13, 17, 18, 21, 26, 27, 29; PE 7, 9, 15, 16, 17, 20, 21, 27, 29.

**DISCUSSION**

Of the 26 different taxa reported, 62% were common to the ponds of the central and the eastern parts of the country. *Closterium cynthia*, *C. macilentum*, *C. praelongum* var. *praelongum*, *C. pseudolunula*, *C. striolatum* and *C. subfusiforme* were confined to the ponds of the central part of the country. *C. ehrenbergii* var. *atumidum*, *C. ehrenbergii* var. *malinvernianum*, *C. leibleinii* and *C. malmei* var. *semicirculare* were only found in the ponds of the eastern part.

In the two parts of the study area, species of *Closterium* were collected in ponds characterized by acidic to alkaline waters (pH-values: 5.5-9.8). Different species were encountered among the phytoplankton community in ponds. This genus is known to be present in acid, oligotrophic waters of lakes and ponds (Prescott *et al.*, 1975). Morphometry of water body, water movement and aeration are possible factors affecting the abundance of desmids (Bland & Brook, 1974; Coesel, 1975 and Kadiri, 1993).

The shallow nature of ecosystems and low conductivity of water affect the relative abundance of desmids (Kadiri, 1993) including *Closterium*. In the study area, ponds were oligotrophic according to the concentration of nitrates ( $< 2.5 \text{ mg l}^{-1}$ ) measured. The ponds have small dimensions with shallow depths (maximum 52 cm) and small surfaces (maximum 250  $\text{m}^2$ ); most are located near agglomerations and agricultural fields. The values of physico-chemical parameters of freshwater ponds as conductivity, depth, concentration of nitrates and phosphates, dissolved oxygen during some visits for sampling could explain the presence of some species of *Closterium* in ponds. However, all species were recorded in all ranges of pH (acidic or alkaline), transparency, salinity, nitrate or phosphate concentrations measured in ponds (Table 1), except *C. leibleinii*, *C. pseudolunula*, *C. striolatum*, *C. subfusiforme*, *C. praelongum* var. *praelongum*, *C. praelongum* var. *brevius*, *C. tumidulum* and *C. ehrenbergii* var. *atumidum*. Indeed, considering pH of water in ponds, *C. subfusiforme* and *C. praelongum* var. *praelongum* can be considered as neutrophiles (pH: 5.5-8.5) and *C. malmei* var.

Table 1. Mean values of physical and chemical parameters in the studied ponds. DO = dissolved oxygen.; transp. = transparency, PC : ponds localised in the central part; PE: ponds localised in the eastern part. All nutrient concentrations are given in  $\text{mg l}^{-1}$

Sites	Surface ( $\text{m}^2$ )	Depth (cm)	Transp. (cm)	pH	Conductivity ( $\mu\text{S cm}^{-1}$ )	Salinity (ppm)	Ammonia	Nitrates	DO	Phosphates
PC1	156	18	5	8.8	71	31	1.15	0.25	9	0.12
PC2	75	23	6	8.12	49	24	0.38	1.75	9	0.25
PC3	44	14	3	8.68	189	100	2.28	2.25	7	0.17
PC4	12	20	6	7.81	47	22	0.3	0.75	8	0.35
PC5	31	23	9	8.24	36	18	0.26	1	8	0.25
PC6	91	18	10	9.31	33	15	0.18	0.5	9	0.15
PC7	62	29	13	9.42	22	10	0.3	2.5	8	0.17
PC8	107	24	13	8.16	48	23	0.53	2	5	0.4
PC9	52	23	5	8.37	136	72	0.7	1.5	9	0.52
PC10	56	25	8	8.72	26	13	0.25	0.5	8	0.17
PC11	210	32	18	8.22	30	15	0.15	1.75	8	0.17
PC12	75	13	10	8.09	55	27	0.25	2.25	9	0.22
PC13	23	24	15	8.18	132	65	0.26	1	7	0.47
PC14	92	18	4	9.14	100	49	0.18	1.5	9	0.47
PC15	24	21	8	7.83	57	29	0.15	1.5	8	0.12
PC16	3	2	2	8.53	14	7	0.18	1.25	8	0.27
PC17	50	21	8	8.17	49	23	0.28	1.25	8	0.07
PC18	52	26	13	7.9	38	18	0.2	1.5	8	0.17
PC19	9	8	8	8.13	28	13	0.4	1.75	8	0.32
PC20	70	33	11	8.44	33	17	0.26	1.25	9	0.17
PC21	56	20	12	8.15	47	22	0.3	0.75	9	0.3

Table 1. Mean values of physical and chemical parameters in the studied ponds. DO = dissolved oxygen.; transp. = transparency; PC: ponds localised in the central part; PE: ponds localised in the eastern part. All nutrient concentrations are given in  $\text{mg l}^{-1}$

Sites	Surface ( $\text{m}^2$ )	Depth (cm)	Transp. (cm)	pH	Conductivity ( $\mu\text{S cm}^{-1}$ )	Salinity (ppm)	Ammonia	Nitrates	DO	Phosphates
PC22	70	26	13	8.37	74	35	0.55	0	5	0.22
PC23	15	13	9	7.33	38	20	0.28	1	7	0.12
PC24	37	17	15	8.18	40	20	0.13	0.75	9	0.2
PC25	31	19	12	8.29	21	10	0.26	1	9	0.17
PC26	14	7.5	6	8.26	50	25	1.81	1	8	0.25
PC27	36	13	11	9.08	39	19	0.88	1.75	8	0.22
PC28	150	4	3	5.57	78	39	0.13	0.75	4	0.07
PC29	35	11	9	7.6	42	18	0.13	1	8	0.15
PC30	12	4	4	5.88	75	36	0.15	0	6	0.22
PE1	32	22.5	8	8.62	113	55	0.25	1	6	0.21
PE2	16	13	7	8.66	54	25	0	0.25	10	0.05
PE3	16	31	12	9.09	103	50	0.59	0.25	10	0.75
PE4	7	49	12	8.58	62	30	0.15	0.25	9	0.6
PE5	35	20	15	8.4	55	27	0.13	1.5	9	0.35
PE6	65	23	23	8.51	27	13	0.18	0.5	8	0.25
PE7	38	52	6	8.56	110	54	0.34	1.5	7	0.25
PE8	24	14	5	8.08	63	31	0.25	1.75	7	0.37
PE9	62	26	15	8.52	63	31	0.06	0	9	0.4
PE10	27	36	18	8.15	91	44	0.15	2	9	0.7
PE11	100	33	4	8.92	65	33	0.31	0.75	9	0.22
PE12	239	37	7	8.88	98	48	0.2	0.75	8	0.57

Table 1. Mean values of physical and chemical parameters in the studied ponds. DO = dissolved oxygen.; transp. = transparency, PC : ponds localised in the central part; PE: ponds localised in the eastern part. All nutrient concentrations are given in  $\text{mg l}^{-1}$

Sites	Surface ( $\text{m}^2$ )	Depth (cm)	Transp. (cm)	pH	Conductivity ( $\mu\text{S cm}^{-1}$ )	Salinity (ppm)	Ammonia	Nitrates	DO	Phosphates
PE13	48	13	5	8,61	135	66	0,2	0	5	0,47
PE14	143	6	4	8,71	178	91	1,05	2	5	0,4
PE15	52	34	9	8,03	66	33	0,2	0	9	0,3
PE16	23	23	13	8,95	69	34	0,03	0,5	10	0,17
PE17	9	22	13	9,35	144	72	0,33	0,58	9	1,17
PE18	45	22	20	8,67	63	31	0,1	0,75	6	0,57
PE19	22	10	10	9,13	29	14	0	0,5	9	0,5
PE20	76	35	25	8,73	96	47	0,28	0,5	8	0,6
PE21	10	14	6	9,74	106	51	0,2	1	9	0,5
PE22	45	15	13	8,75	86	42	0,05	0,5	8	1,77
PE23	64	16	14	8,73	167	83	0,41	0,5	7	0,95
PE24	15	9	9	9,58	15	6	0,23	1	9	0,2
PE25	21	16	11	8,89	29	14	0,35	1	8	0,17
PE26	40	20	13	8,85	36	17	0,25	1,5	7	0,12
PE27	16	16	10	8,82	245	122	0,25	0	4	0,57
PE28	27	19	19	9,14	38	18	0,03	0,5	8	0,2
PE29	61	18	15	8,77	110	54	0,18	1	9	0,55
PE30	10	8	8	8,57	71	35	0	1	8	0,6
PE31	24	17	9	7,928	159	78	0,42	0,5	8	1,07

*semicirculare* and *C. ehrenbergii* var. *atumidum* as alkalophiles (pH: 8.5-12) according to the classification of freshwater microbes in relation to pH (Sigee, 2005). The other species were found in neutral as well as in alkaline habitats.

*Closterium pseudolunula*, *C. subfusiforme*, *C. ehrenbergii* var. *atumidum* and *C. praelongum* var. *brevius* were recorded in water with a transparency ranging from 2 to 10 cm, while *C. praelongum* var. *praelongum* was recorded in water with a transparency ranging from 11 to 23 cm. *C. pseudolunula*, *C. striolatum*, *C. cynthia*, *C. ehrenbergii* var. *atumidum*, *C. subfusiforme* and *C. praelongum* var. *praelongum* were only recorded in ponds with a salinity ranging from 7 to 51 ppm. The concentration of nitrates ranged from 0 to 2.5 mg l<sup>-1</sup> (Table 1) but *C. leibleinii*, *C. tumidulum*, *C. praelongum* var. *praelongum* and *C. ehrenbergii* var. *atumidum* were only recorded in water with a nitrate concentration ranging from 0 to 1 mg l<sup>-1</sup> and *C. subfusiforme* was recorded in water with a nitrate concentration ranging from 1 to 2.5 mg l<sup>-1</sup>.

We also found species present with low frequencies, ranging from 1% to 17% of all ponds, with acidic as well as with alkaline waters. A few species occur in alkaline and eutrophic ecosystems (Prescott *et al.*, 1975). These frequencies do not reflect obligatory favourable conditions for the development of species of *Closterium*. Furthermore, although certain groups of green algae as *Closterium* may have ecological demands (Sheath & Wehr, 2003), some species have abilities to grow in certain unfavourable conditions in aquatic ecosystems. For example, according to (Sheath & Wehr, 2003), *C. acutum* is planktonic in eutrophic water, often among Cyanobacterial blooms. The species most frequently met in the present study are *Closterium acerosum* var. *minus*, *C. venus*, *C. acutum* var. *latius*, *C. ehrenbergii* var. *ehrenbergii* and *C. lineatum*, present in 17%, 17%, 16%, 14%, and 10% of all ponds, respectively.

Of the species found, 38% had already been reported from Burkina Faso, namely *Closterium acerosum* var. *minus*, *C. acutum* var. *latius*, *C. cornu*, *C. ehrenbergii* var. *ehrenbergii*, *C. leibleinii*, *C. praelongum* var. *praelongum*, *C. praelongum* var. *brevius*, *C. pseudolunula*, *C. ralfsii* var. *hybridum* (Zongo & Guinko, 1999; Zongo, 2007). The rest of the taxa can be considered as new for the country. To our knowledge, 61% of the species were already reported from West Africa.

In comparison with other West African countries, many of the species have already been reported from Côte d'Ivoire (47%) in previous studies. This could be the result of the fact that more studies on micro-algae have been conducted in this country comparatively to other countries of West Africa.

Among the reported species of *Closterium*, 81% were already met in Africa according to the literature at our disposal. 73% of these species are cosmopolitan. The others are confined to some regions of the world particularly in the tropical ones.

## CONCLUSIONS

In temporary ponds, species of *Closterium* are found in acidic and alkaline waters but with low frequencies. Species of this genus are likely to be confined to acidic and oligotrophic ponds (Prescott *et al.*, 1975). However, some species are able to thrive in alkaline waters, under generally unfavourable conditions for the desmids group. Most species recorded in this study are neutrophiles and alkalophiles. With 26 species described from 61 ponds collected during four visits, temporary ponds can not be considered as favourable ecosystems for the development of species of this genus.

This investigation in ponds allows us to add a number of representatives of the genus *Closterium* to the flora of Burkina Faso. Although the majority of the observed species of *Closterium* are cosmopolitan and already met in many localities of Africa, nevertheless, for Burkina Faso, this study provides an appreciable contribution to the knowledge of its algal flora.

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