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Taxonomical diversity of Genus *Phacus* (Dujardin, 1841) in different wetlands of Bhagalpur District, Bihar, India

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Abstract
Genus *Phacus*, is one of the important group of class Euglenophyceae which is primarily freshwater inhabitants and are unicellular excavates. The present paper is an attempt to explore the *Phacus* diversity and to make a taxonomical account on it, from different selected wetlands of Bhagalpur District, Bihar. The algal samples were collected seasonally from the wetlands located in the sixteen blocks of Bhagalpur district. The study was conducted from December 2020 to June 2022, using the standard methods. During the period of study a total of 19 taxa of Genus *Phacus* were recorded from various wetlands of the district. The *Phacus* community in the present study includes the following taxa: *Phacus chloroplasts, P. tortus, P. applantus, P. longicauda, P. undulates, P. inflatus, P. pleuronectes, P. orbicularis, P. caudatus, P. ankylonoton, P. curvicauda, P. acuminatus, P. limnophila, P. monilatus* Var. *suecicus, P. balatonicus* Var. *major, P. viguieri, P. circulates, P. nordstedii, P. lismorensis.*

Keywords: Euglenophyceae, freshwater, *Phacus*

Introduction
Phacus was described in the 19th century by (Dujardin, 1841) [5] is a morphologically green leaf shaped distinctive photosynthesis euglenoids. The name *Phacus* comes from a Greek word *Phakos*, meaning lentil or lens. They are heart shaped, unicellular, flat, rigid, and with true compressed cell wall. The cell also consist of eyespot and swelled flagella in some of the species. They are relatively easier to study compared to the metabolic cell of *Euglena.* They are mostly found in shallow and stagnated or flowing water, as moist soil, ditches, puddles, ponds. They are often predominant in eutrophic water including high organic and inorganic contents (Rahman *et al.* 2014) [18]. It consist of approx 300 species names, of which 173 are taxonomically accepted. (Guiry and Guiry, 2000) [7]. They are one of the most important part of the aquatic food chain in the form of primary producers of organic matter in nature, thus playing a major role a basic constituent of living community. They also have a notable role in ecological aspects, markedly as pollution indicator (Palmer, 1969) [14]. In India, listed publications on Euglenophyceae diversity in the past five years (Ekhande, 2017; Patil and Kumawat, 2020; Baruah *et al*., 2020; Maland Keshri, 2022; Sharma and Hatimuria, 2017; Kadam *et al*., 2020; Dash *et al*., 2021) [6, 15, 2, 20, 8, 4]. The present work is an attempt to explore the genus *Phacus* diversity and make a taxonomic account on it from the selected wetlands of Bhagalpur District, Bihar.

Study Area
Bhagalpur district is located in the eastern part of the state and extends between the northern latitudes of 25° 03'40" and 25°30'00" and eastern longitudes of 86°30'00" and 87°29'45". The district is a peneplain, intersected by numerous streams. Geomorphologically, the district of Bhagalpur forms a part of the Mid-Ganga Foreland Basin. The north and central Bhagalpur towards the north and south of Ganga respectively forms a monotonously flat Indo-Gangetic alluvium tract. Surface level varies due to high banks of the Ganga, Kosi, Chanari and Chandan. The southern part of the district forms a marginal alluvial tract. The general elevation of the alluvium tract remains within 45 m above mean sea level (AMSL). Bhagalpur Sadar, Kahalgaon, and Naugachhia are the three sub-divisions of the district with a total of sixteen community development blocks namely Pirpainti, Kahalgaon, Sanhoula, Sabour, Nathnagar, Jagdishpur, Sultanganj, Shahkund, Bihpur, Naugachhia, Gopalpur, Kharik, Narayanpur, Goradih, Ismailpur, and Rangra chowk. The selected sampling sites from all the sixteen blocks have been shown in Fig.1.

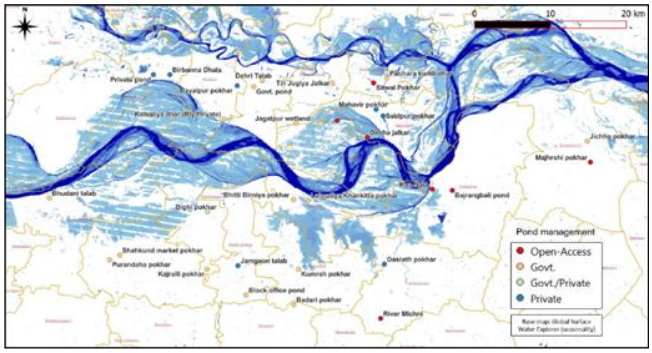


Fig 1: Different Sampling Sites of Bhagalpur District

Material and Methods
Water samples for phytoplankton qualitative analysis was collected seasonally from all the selected wetlands from all the 16th blocks of Bhagalpur district from December 2020 to June 2022. From all the 32 sampling stations water samples was filtered through a phytoplankton net of 65µmesh size. All the filtered contents was then transferred to 125 ml container. The filtrate was immediately preserved in 4% formaldehyde and was transported to the Environmental Biology Research Laboratory of University Department of Botany, T. M. Bhagalpur University. The transported samples were analyzed following standard method (APHA, 2005). The algal taxa were observed under a light microscope with a high magnification of 45X. For

taxonomic diversity studies camera lucida technique was adopted for writing diagram. For current publication of manuscript only photographic images have been used in (Plate – I & II). *Phacus* was identified up to species level using relevant literature and monographs on algal taxonomy (Prescott 1962, Philipose 1984, Kouassi *et al.* 2013, Satpati and Pal, 2017) [17, 10, 19].

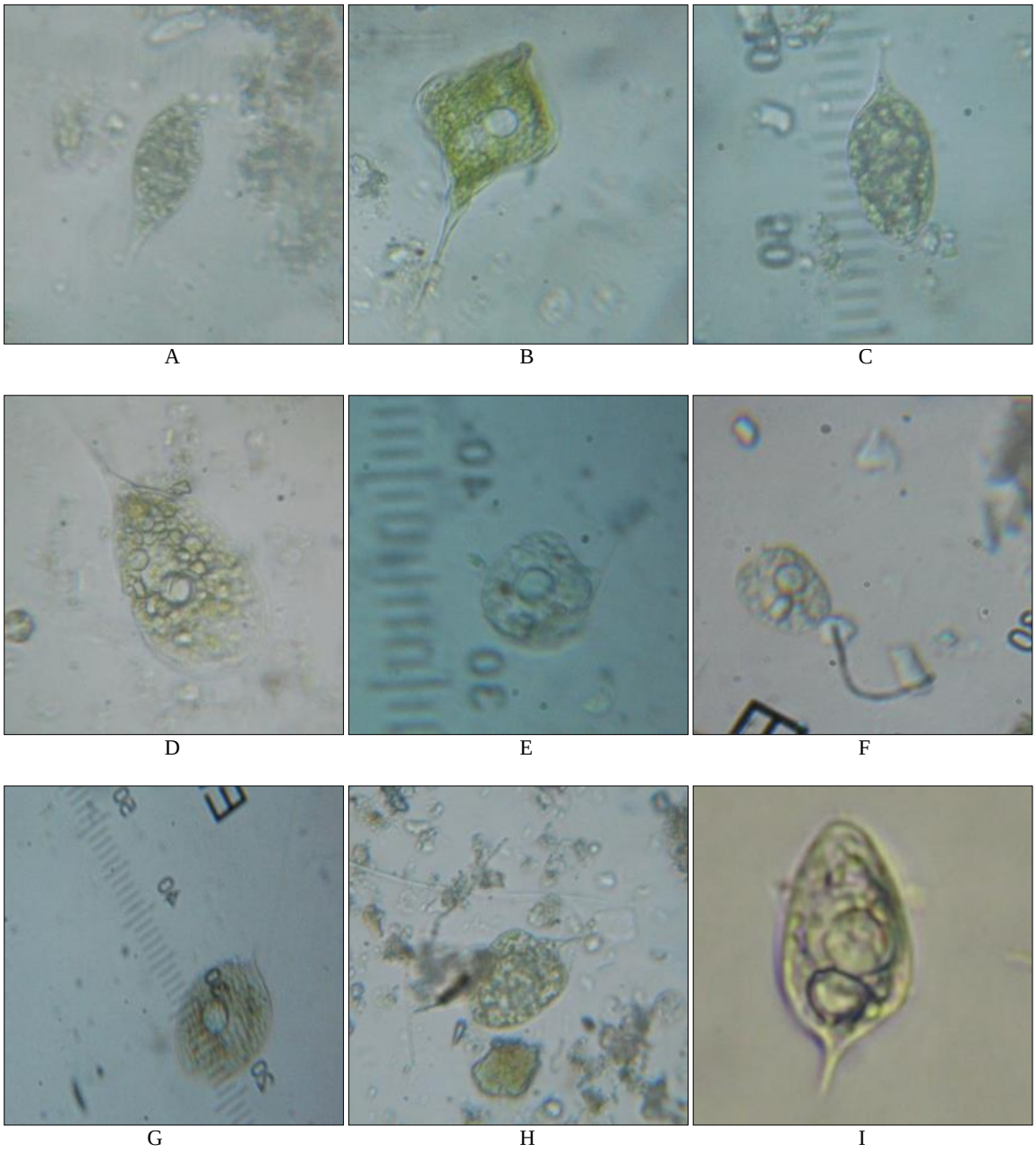
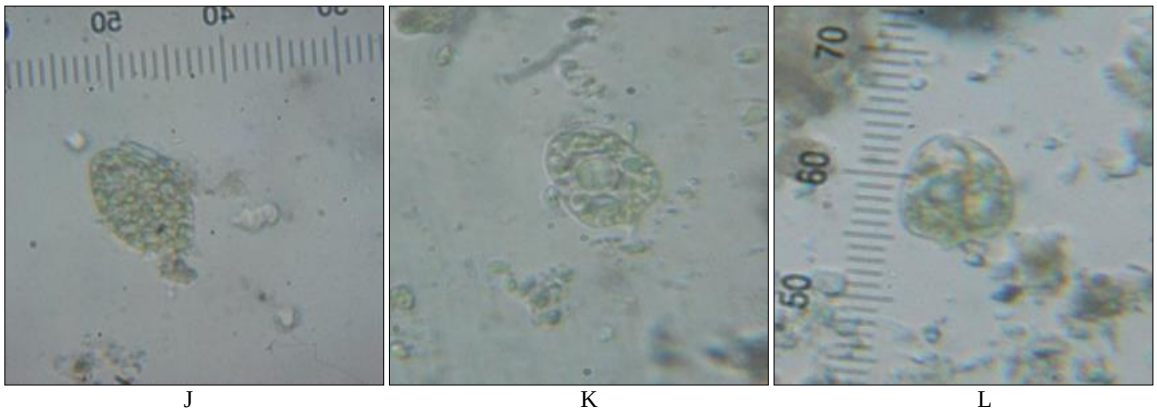


Fig 2: (A) *Phacus chloroplasts,* (B) *Phacus tortus* (C) *Phacus applantus,* (D) *Phacus longicauda,* (E) *Phacus undulatus,* (F) *Phacus inflatus,* (G) *Phacus pleuronectes,* (H) *Phacus orbicularis,* (I) *Phacus caudatus,* (Scale 45µm)



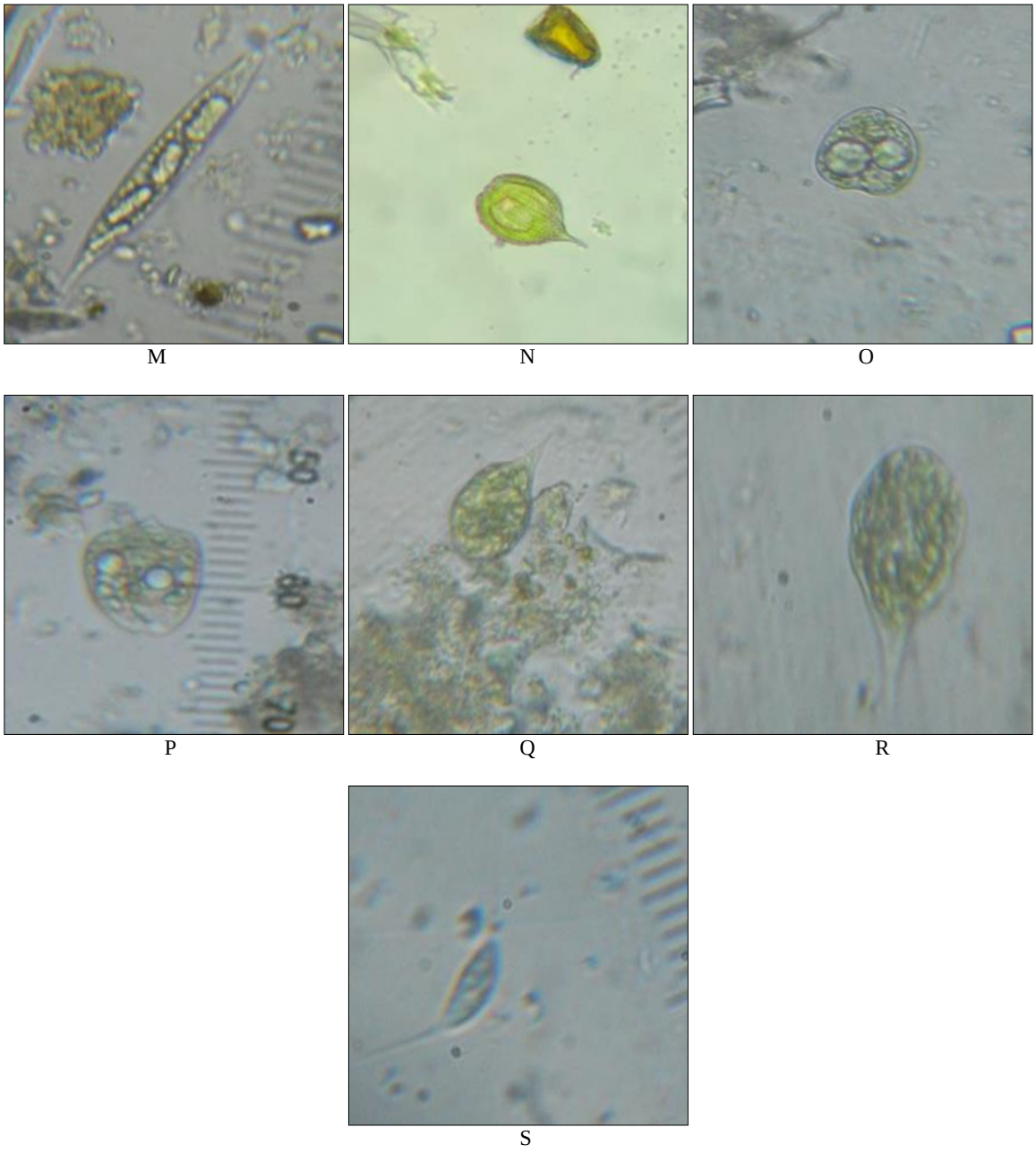


Fig 3: (J) *Phacus ankylonoton,* (K) *Phacus curvicauda,* (L) *Phacus acuminatus,* (M) *Phacus limnophila,* (N) *Phacus monilatus* Stokes Var. *suecicus,* (O) *Phacus balatonicus* Var. *major,* (P) *Phacus viguieri,* (Q) *Phacus circulates,* (R) *Phacus nordstedii,* (S) *Phacus lismorensis* (Scale 45µm).

Results

In the present study, 19 taxa of the genus *Phacus*, freshwater free-swimming Euglenophytes, was recorded and described. The following are the taxonomical comments on the recorded taxa of *Phacus.*

Taxonomy of Euglenophyta

Division - Euglenophyta
Class - Euglenoidea
Order - Euglenales
Family - Phacaceae
Genus – Phacus

Taxonomical identification of taxa *Phacus*

Phacus chloroplasts Prescott 1944 (Fig. A, Pl. I)
Cell pyriform, anterior end broadly rounded, posterior end straight cauda, periplast longitudinal striated, chloroplast several, length 40.7µm, width 18.5µm, anterior width 11.1µm, caudal length 11.1µm, pl 87, fig. 15,16, page 399, G.W. Prescott. 1962.

Phacus tortus **(**Lemmermann) Skvortzov 1928 (Fig. B, Pl. I)
Cell broadly spindle shaped, anterior end broad, conical rounded, and posterior end spirally twisted to form long cauda, chloroplast numerous, tail long and straight. Length 66.6µm, anterior width 29.6µm, posterior width 11.1µm, tail 25.9µm long and 3.7µm width, IJARIIE pl-1, vol.-7, Issue-6, page 158-167, 2021, fig. 4f, *Turkish Journal of Botany* 37: 1176-1187, 2013.

Phacus applantus Pochmann 1942 (Fig. C, Pl. I)
Cell oval, flat anterior wide, posterior narrow, straight tail, length 48.1µm, width 22.2µm, tail 11.1µm long and width 1.8µm; fig. 3(r), *Journal of Phycology* 56: 1135-1156, 2000.

Phacus longicauda (Ehrenberg) Dujardin 1841 [5] (Fig. D, Pl. I)
Cell obovate, broadest in the front half, anterior end broadly rounded, tapering towards posterior, slight curved initial

tail, then long straight, length 125.8µm, width 37µm, tail 51.8µm, fig. 37 a, M T Philipose., Proc. Indian Acad. Sci. (Plant Sci.) vol. 93, No. 5, October 1984, pp. 503- 552.

Phacus undulatus (SKV) Pochmann 1942 (Fig. E, Pl. I)

Cell oval, anterior half narrower, tail small and oblique, middle wide, lateral margin irregular, margin cut into rounded scallops, two central ring, length 37µm, width 22.2µm, tail 7.4µm, fig. 34, M T Philipose., Proc. Indian Acad. Sci. (Plant Sci.) vol. 93, No. 5, October 1984, pp. 503- 552.

Phacus inflatus Playfair 1921 (Fig. F, Pl. I)

Cell in two unequal, inflated, asymmetrical lobes, one lobe larger and other expanded more, short tail with longer lobe, in long lobe large ring, length 48.1µm, width 27.7µm, tail length 7.4µm, fig. 26b, M T Philipose., Proc. Indian Acad. Sci. (Plant Sci.) vol. 93, No. 5, October 1984, pp. 503- 552.

Phacus pleuronectes (OFM) Dujardin1841 [5] (Fig. G, Pl. I)

Cell oval, broad, slight twist, convex one side, apical groove present, posterior end curved tail, length 44.4µm, width 25.9µm, tail length 5.5µm, fig. 27, M T Philipose., Proc. Indian Acad. Sci. (Plant Sci.) vol. 93, No. 5, October 1984, pp. 503- 552.

Phacus orbicularis Huebner 1886 (Fig. H, Pl. I)

Cell circular, dorsal side convex, posterior end short bent tail, pellicle striated, length 48.1µm, width 29.6µm, tail length 11.1µm, fig. 30, M T Philipose., Proc. Indian Acad. Sci. (Plant Sci.) vol. 93, No. 5, October 1984, pp. 503- 552.

Phacus caudatus Huebner 1886 (Fig. I, Pl. I)

Cell oval, slightly twisted, posterior straight short tail, two rings one larger in the middle other smaller, length 33.3µm, width 11.1µm, tail length 3.7µm, fig. 32 b, M T Philipose., Proc. Indian Acad. Sci. (Plant Sci.) vol. 93, No. 5, October 1984, pp. 503- 552.

Phacus ankylonoton, Pochmann 1942 (Fig. J, Pl. II)

Cell oval, irregular crenate (toothed rounded), tail straight, small, pellicular striae longitudinal, length 27.7µm and width 12.9µm, tail length 3.7µm, fig. 33, M T Philipose., Proc. Indian Acad. Sci. (Plant Sci.) vol. 93, No. 5, October 1984, pp. 503- 552.

Phacus curvicauda Swirenko 1915 (Fig. K, Pl. II)

Cell ovoid, anterior slightly narrow, bilobed and furrowed anteriorly to posteriorly, posterior broad, chloroplast numerous, dorsiventral grooved, caudas lightly curved with blunt ending with short tail, length 37µm, width (anterior) 22.2µm, width (middle) 29.6µm, tail length 1.8µm, fig. 2 A-C, Nova Hedwigia 71, 1-2, 37-67, Stuttgart, August 2000, fig. 20 a, M T Philipose., Proc. Indian Acad. Sci. (Plant Sci.) vol. 93, No. 5, October 1984, pp. 503- 552.

Phacus acuminatus (Stokes) Huber-Pest. 1955 (Fig. L, Pl. II)

Cell oval, anterior end slightly narrowed and rounded, posterior border, posterior ending short sharp point groove present, chloroplast small, numerous, one small rounded ring present, length 25.9µm, width 29.6µm, tail length 1.8µm, fig. 17a, M T Philipose., Proc. Indian Acad. Sci. (Plant Sci.) vol. 93, No. 5, October 1984, pp. 503- 552, fig. 4 a, Nova Hedwigia 71, 1-2, 37-67, Stuttgart, August 2000.

Phacus limnophila (Lemmermann) 1898 Lanton & Karnkowska 2012 (Fig. M, Pl. II)

Cell fusiform, chloroplast numerous, paramylon 2, rod shaped, tail straight and short, length 88.8µm, width (apical) 14.8µm, width (middle) 29.6µm, tail length 11.1µm, fig. 3k, *Turkish Journal of Botany* (2013) 37:1178-1187, fig. (4 b and c): *Journal of Phycology* 56: 1135-1156, 2020.

Phacus monilatus Stokes Var. *suecicus* Lemmermann 1913 (Fig. N, Pl. II)

Cell ovoid, side view elliptical, slightly curved tail, anterior end truncate, posterior slightly oblique, chloroplast numerous, periplast strongly warted, length 29.6µm, width 18.5µm, tail length 3.7µm, fig. 45, M T Philipose., Proc. Indian Acad. Sci. (Plant Sci.) vol. 93, No. 5, October 1984, pp. 503- 552, fig. 4 c, *Turkish Journal of Botany* 37:1176-1187, 2013, plate 2 c, Nelumbo, Vol. 64(1):273-289, 2022.

Phacus balatonicus Hortobagyi 1943 Var. *major* M T Philipose 1984 (Fig. O, Pl. II)

Cell broadly oval, both end rounded, apical furrowed reaching hind end, chloroplast numerous, paramylon ring present, length 44.4µm, width (apical) 25.9µm width (middle) 33.3µm, fig. 11, M T Philipose., Proc. Indian Acad. Sci. (Plant Sci.) vol. 93, No. 5, October 1984, pp. 503- 552.

Phacus viguieri P. Allorge & M. Lefevre 1925 (Fig. P, Pl. II)

Cell ovoid, green in color, anterior narrow, posterior broad and short tail piece, chloroplast numerous, paramylon two, rounded, length 40.7µm, width 25.9µm, tail length 1.8µm, pl. III, fig. 18,Hydrobiol. Trop. 27(1):3-21, 1994, fig. 1 u, *Phykos* 47 (1): 105-122, 2017.

Phacus circulates Pochmann1942 (Fig. Q, Pl. II)

Cell ovoid, green, anterior narrow, middle broad, posterior part form cauda, paramylon single, large plate like in the middle, chloroplast numerous, tail short, length 37µm, width 25.9µm, tail length 3.7µm, fig. 1(P), *Phykos* 47 (1): 195-122, 2017, fig. 3 g, *Turkish Journal of Botany* 37:1176-1187, 2013.

Phacus nordstedii Lemmermann 1904 (Fig. R, Pl. II)

Cell napiform, green, anterior broadly rounded, posterior narrow, straight pointed cauda, pellicle spirally striated, chloroplast numerous, length 59.2µm, width 35.1µm, tail length 18.5µm, pl- 4, fig. 3, pp 1-34, Kasetsart University Fisheries Bulletin No. 27, 2004.

Phacus lismorensis Playfair 1921 (Fig. S, Pl. II)

Cell long ovate, green in color, flat, curved structure, anterior end wide, rounded, posterior end gradually narrowed and terminated with a long tail, length 74µm, width 18.5µm, tail length 21µm, fig 4(n), *Journal of Phycology* 56: 1135-1156, 2020.

Discussion

In the present study a total of 19 taxa of *Phacus* was reported from all the selected wetlands of Bhagalpur District along with other taxa of Class Euglenophyceae. The presence of taxa like *Phacus acuminatus, P. applantus, P. curvicauda, and P. longicauda* were present frequently and commonly reported from all the selected wetlands. The other *Phacus* species were less abundant and were rare like *P.lismorensis, P. tortus, P.pleuronectes, P.monilatus* Var. *suecicus* and *P. nordstedii.* The presence of Euglenophytes were highest number of count in summer season while minimum number of count was recorded during monsoon season. The high number of euglenoids in the water bodies indicates organic pollution (Wolowski 1998, 2011) [23-24]. According to Palmer (1969) [14] the presence of Genus *Phacus* is evidence of organic pollution. The occurrence of Euglenophytes in selected wetlands also indicates that it may proceed towards eutrophic condition as they acts as good pollution indicators. The reason for Euglenophytes bloom are activities like entry of huge sewage, cattle

washing, fishing, runoff from surrounding residential areas and other anthropogenic pollution. Such activities increase the concentration of chemical like nitrate and phosphate which stimulates the growth of phytoplankton in large quantities (USEPA, 1973). According to (Trivedy and Goel, 1986) [21] entry of nitrate in water, increase the growth of nuisance algae, microphytes and trigger eutrophication. Therefore, knowledge of the Euglenophyta flora can be useful in the assessment of water quality and also be helpful in deriving the conservational strategies for protection of these wetlands.

Conclusion

This study was to explore the diversity of *Phacus* of some of the selected wetlands of Bhagalpur district. From the result it may be concluded that the ecological conditions of the wetlands support rich diversity of Euglenoids in Bhagalpur district.

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Author's Contribution

Shadia Rahman (1st author) and Braj Nandan Kumar (3rd author) contributed in laboratory analysis, taxonomic identification of *Phacus* species and collected the data.1st and 3rd author contributed in the preparation and writing of the manuscript. Sunil Kumar Choudhary (2nd author) reviewed and revised the draft and approved the submission of the manuscript.

Conflict of interest: The authors declare that there is no conflict of interest regarding publication of this manuscript.

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