A TAXONOMIC STUDY ON SOIL TAXA OF ANABAENA BORY EX BORENTE FLAHAULT (NOSTOCACEAE) IN IRAN

Z. Shariatmadari, H. Riahi & S. Shokravi

Received 15.10.2010. Accepted for publication 02.03.2011.

Shariatmadari, Z., Riahi, H. & Shokravi, S., 2011: A taxonomic study on soil taxa of Anabaena Bory ex Bornet et Flahault (Nostocaceae) in Iran. ± QD - %R - 7H KDQ

In a revision of the genus Anabaena Bory ex Bornet et Flahault (Nostocaceae) in terrestrial habitats, 33 specimens belonging to eleven species and one variety were identified. Specimens were collected from 18 paddy field soils located in seven provinces of Iran. $QDQ WRU DKL, N. L. Gardner, $RU L H Q W D O L V Dixit and $JP ELJX DC. B. Rao are reported as five new records from Iran. An identification key, description and pictures of these species are presented in this study.

INTRODUCTION
The genus Anabaena Bory ex Bornet et Flahault, is one of the nostocacean cyanobacteria. Nostocacean cyanobacteria are filamentous, heterocystous, not branched and not polarized morphotypes, classified traditionally in Nostocaceae family (Komárek 2010). These are cosmopolitan microorganisms, which play significant roles in diverse ecosystems such as paddy fields. The paddy field ecosystem represents a favorable environment for the growth of cyanobacteria fulfilling the requirements of light, water, temperature, humidity and nutrient availability in an optimal manner (Prasanna & Nayak 2007). Up to now, several species from different genera of Nostocaceae were reported from paddy fields of Iran but most of records related to northern provinces of Iran. Report of two species of Anabaena from paddy fields of Gilan province in 1995 was the first record of this genus from paddy soils of Iran (Abrkar & Riahi 1995). Nowruz & Ahmadimoghdam (2006) reported four species of Anabaena from paddy fields of Golestan province and also Saadatnia & Riahi (2009) reported four species and Shariatmadari & Riahi (2010) reported 4 species and one variety of this genus from Gilan province. This study is focused on seven main rice cultivation provinces situated in north, centre, south, west and east of Iran. In present study, an attempt is made to contribute a new knowledge about Anabaena species and their distribution in the terrestrial ecosystems.
Table 1. Geographical details of the sampling locations.

<table>
<thead>
<tr>
<th>Location</th>
<th>Geographic location</th>
<th>Province</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rostamabad</td>
<td>36°53’ N 49°20’ E</td>
<td>Gilan</td>
</tr>
<tr>
<td>Omsheh</td>
<td>37°16’ N 49°35’ E</td>
<td>-</td>
</tr>
<tr>
<td>Saravan</td>
<td>37°05’ N 49°24’ E</td>
<td>-</td>
</tr>
<tr>
<td>Rahimabad</td>
<td>36°51’ N 50°13’ E</td>
<td>-</td>
</tr>
<tr>
<td>Tonkabon</td>
<td>36°48’ N 50°52’ E</td>
<td>Mazandaran</td>
</tr>
<tr>
<td>Tazehabad</td>
<td>36°39’ N 51°25’ E</td>
<td>-</td>
</tr>
<tr>
<td>Alamut</td>
<td>36°23’ N 50°33’ E</td>
<td>Qazvin</td>
</tr>
<tr>
<td>Visan</td>
<td>33°49’ N 48°07’ E</td>
<td>Lorestan</td>
</tr>
<tr>
<td>Ebrahimabad</td>
<td>29°00’ N 52°56’ E</td>
<td>Fars</td>
</tr>
<tr>
<td>Easmaeelabad</td>
<td>28°85’ N 53°83’ E</td>
<td>-</td>
</tr>
<tr>
<td>Fathabad</td>
<td>29°19’ N 52°37’ E</td>
<td>-</td>
</tr>
<tr>
<td>Kamfiroz</td>
<td>30°15’ N 52°17’ E</td>
<td>-</td>
</tr>
<tr>
<td>Ghahdarjan</td>
<td>32°30’ N 51°30’ E</td>
<td>Esfahan</td>
</tr>
<tr>
<td>Falavarjan</td>
<td>32°32’ N 51°30’ E</td>
<td>-</td>
</tr>
<tr>
<td>Jujil</td>
<td>32°34’ N 51°28’ E</td>
<td>-</td>
</tr>
<tr>
<td>Zarrinshahr</td>
<td>32°22’ N 51°22’ E</td>
<td>-</td>
</tr>
<tr>
<td>Varnamkhash</td>
<td>32°21’ N 51°22’ E</td>
<td>-</td>
</tr>
<tr>
<td>Kalat</td>
<td>36°59’ N 59°47’ E</td>
<td>Khorasan Razavi</td>
</tr>
</tbody>
</table>

MATERIALS AND METHODS

Soil samples were collected from 18 paddy fields from April 2008 to May 2010 (Table 1) according to Rangaswamy method (1996). The collected soil samples were transferred to sterile petri dishes and sterilized nitrate free BG-11 medium (Stanier & al. 1971) was added and the pH adjusted in 7.1 after sterilization. The petri dishes were placed in a culture chamber at 25±5°C and a 12/12h light-dark cycle at artificial illumination (2000-2500 Lux) for two weeks. After colonization, cyanobacteria were transferred to the agar plates for purification. Taxonomic determination was carried out by light microscopy and based on Desikachary (1959), Prescott (1970), Wehr & al. (2002), Whitford & Schumacher (1973), Komárek (2005) and Komárek & Zapošmelová (2008) by prepared semipermanent slides. The vegetative and reproductive characters used in the taxonomic determination were: Shape, color and size of the thallus; wide and length of trichomes; shape, size and color of vegetative cells, heterocysts and akinetes; as well as texture, color and ornamentation of cell walls of the akinetes and heterocyst.

RESULTS AND DISCUSSION

In this study, 33 specimens belonging to eleven Anabaena morphospecies and one variety were identified (Figs. 7, 8). All species and their distribution are listed in Table 2.

A key to Anabaena species distributed in paddy fields soil of Iran

1. Trichomes with terminal heterocyst  A. oryzae (4)  Trichomes often without terminal heterocyst  2

2. Akinetes spherical or sub-spherical  3

3. Akinetes not spherical  5

4. Akinetes one to few together. Cells discoid  A. sphaerica (8)

5. Akinetes regularly in even size  A. fertilissima (2)

6. Akinetes in long series  A. variabilis var. ellipsospora (10)

7. Heterocysts spherical or sub-spherical  A. vaguieri (11)

8. Heterocysts otherwise  10


10. Akinetes ellipsoidal or oblong  11

11. A. orientalis (6)

12. Apical cells rounded. Akinetes oblong, several in both sides of heterocyst  A. oscilarioides (5)

13. Apical cells conical. Akinetes ellipsoidal, one in both sides of heterocyst  A. orientalis (6)
Table 2. List of soil *Anabaena* species recorded from Iran and their distributions.

<table>
<thead>
<tr>
<th>Species</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>A. ambigua</em> C. B. Rao</td>
<td>+</td>
<td>+</td>
<td>-</td>
<td>-</td>
<td>+</td>
<td>+</td>
<td>-</td>
</tr>
<tr>
<td><em>A. fertilissima</em> C. B. Rao</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>-</td>
<td>+</td>
<td>-</td>
</tr>
<tr>
<td><em>Anabaena sp</em></td>
<td>+</td>
<td>+</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>


1. *A. ambigua* C. B. Rao, Proc. Indian Acad. Sci., B, 5:101, 1937. Fig. 1 A
   *HAFUS\(\) MRQ* Trichome free or enclosed in a mucilaginous envelope, straight, shortly narrowed at the ends, clearly constricted at cross walls, with terminal cells widely rounded. Cells shorter than wide, discoid, 9 µ broad, 5-7 µ long, with pale blue-green, slightly granulated contents. Heterocysts spherical or sub-spherical, 9-10 µ broad. Akinetes ellipsoidal or widely oval, arise on both sides of heterocysts, usually with granular contents, 14-16 µ broad, 14-27 µ long.
   *QEEFH* was reported from the paddy fields and ponds of India, Pakistan and Cuba (Komárek 2005, Naz & al. 2004).

2. *A. fertilissima* C. B. Rao, Proc. Indian Acad. Sci., B, 6: 363, 1937. Fig. 1 B
   *HAFUS\(\) MRQ* Trichome single, straight or bent. Cells barrel-shaped, 6 µ broad, 5 µ long, with rounded apical cells. Heterocysts sub spherical, 5-7 µ broad. Akinetes in long chains, often making the whole trichome sporogenous, adjoining the heterocysts, almost spherical, with a smooth hyaline outer wall, 8 µ broad, 9 µ long.
Syn.: $\text{HNFUSW}_OQ$, $\text{UQ}$, $\text{UD}$.

Lorestan: Visan (33° 49´ N 48° 07´ E).

3. **A. iyengarii** Bharadvaja, Proc. Indian Acad. Sci., B, 2: 105, 1935. Fig. 2 A

\text{HNFUSW}_OQ Trichome single, straight or irregularly curved, not attenuated towards ends, distinctly constricted at cross walls. Cells barrel shaped, with blue-green content, 3-4.5 µ broad, 3-5 µ long; apical cells rounded or conical or rounded apex. Heterocysts spherical or elongated spherical, 6-6.5 µ broad, 7-7.5 µ long. Akinetes arise on both sides of heterocysts, ellipsoidal, 6-8.5 µ broad, 7-14 µ long.

\text{HNFUSW}_OQ, $\text{HQDLXIL}$ was recorded from pools and puddles, rice fields, swamps and littoral zones of ponds and lakes of India, Pakistan, Cuba and Iran (Desikachary 1959, Naz & al. 2004, Komárek 2005, Shariatmadari & Riahi 2010).


4. **A. oryzae** Fritsch, J. Indian Bot. Soc., 28: 135, 1949. Fig. 2 B

Syn.: $\text{JHMQRO}$ Fritsch ex De 1939 $\text{QRP}_OQ\text{QGNN}_Q$ non Reinsch non Wood.

This name is currently regarded as a taxonomic synonym of $\text{1RWF}_R\text{RS}_L\text{DH}_H$ (F. E. Fritsch) Komárek & Anagnostidis

\text{HNFUSW}_OQ Thallus green, gelatinous, membranous. Trichomes short, straight. Cells barrel-shaped, 1-2.5 times as long as broad, 4 µ broad, 5 µ long. Heterocysts terminal and intercalary; intercalary heterocysts sub-spherical, 4-5 µ broad, 4-5 µ long; terminal heterocysts conical and longer than broad, 3.5-3.5 µ broad, 4-4.5 µ long. Akinetes 3-6 in series, sub-spherical, 5-6 µ broad, 6-7 µ long.

\text{HNFUSW}_OQ, $\text{RS}_L\text{DH}_H$ was reported from paddy fields of Pakistan and Iran (Desikachary 1959, Naz & al. 2004, Shariatmadari & Riahi 2010).


5. **A. oscilarioides** Bory ex Born. et Flah., Dict., class. $\text{OIRKQWW}$ Fig. 3 A

\text{HNFUSW}_OQ Thallus gelatinous, yellowish green. Trichome 4-5 µ broad. Cells barrel-shape, somewhat longer than broad, 4-5 µ broad, 8 µ long; apical cells rounded. Heterocysts oval or ellipsoidal with rounded ends, 5-6 µ broad, 8 µ long. Akinetes oblong or cylindrical with rounded ends, contiguous with the heterocysts, one or 2-3 in both sides of heterocyst, rarely up to 4 in chain, 5-7 µ broad, 8-20 µ long; epispore smooth.

\text{HNFUSW}_OQ, $\text{RHMDBV}_C$ is common in several regions of the world. From Asia, this species was reported from Myanmar (Skuja 1949), India (Carter 1926, Gonzalves & Joshi 1946), Pakistan (Naz & al. 2004) and also from paddy fields of Iran (Nowruz & Ahmadimoghadam 2006, Sadatnia & Riahi 2009).


6. **A. orientalis** Dixit, Proc. Indian Acad. Sci., B, 3: 101, 1936. Fig. 3 B

\text{HNFUSW}_OQ Trichome single, straight. Cells sub-quadrate, 2-3 µ long, 2.5-3 µ broad; end cell conical with rounded apex. Heterocysts single, intercalary, cylindrical with rounded apex, 5-7 µ long, 3-4 µ broad. Akinetes one on each side of a heterocysts, ellipsoidal, 7-15 µ broad, 5-6 µ long.

\text{HNFUSW}_OQ, $\text{RHMDBV}_C$ was reported from aquatic ecosystems of India and rice fields of Pakistan (Desikachary 1959, Naz & al. 2004).

\text{HNFUSW}_OQ, $\text{UQ}$, $\text{UD}$ Khorasan Razavi: Kalat (36° 59´ N 59° 47´ E).

7. **A. portoricensis** N. L. Gardner, Mem. New York Bot. Garden 7: 62, 1927. Fig. 4 A

\text{HNFUSW}_OQ Trichomes single, straight or bent, with rounded end cells. Cells barrel-shaped, 4-6 µ long, 4.5 µ broad, with pale blue-green contents, usually granulate. Heterocysts almost spherical or sub-spherical, 6-8 µ broad, with homogeneous, yellow-green contents. Akinetes ripen very irregularly and within rows occur in uneven size, spherical, with blue-green, granular contents, slightly brownish endospore and colourless exospores, 8-9 µ broad, 9-10 µ long.

\text{HNFUSW}_OQ, $\text{SRWRLH}_M$ was originally described by Gardner (1927) from a ditch in Puerto Rico and also was reported from the Caribbean region and old paddy fields of Cuba (Komárek 2005).

\text{HNFUSW}_OQ, $\text{UQ}$, $\text{UD}$ Khorasan Razavi: Kalat (36° 59´ N 59° 47´ E).

8. **A. sphaerica** Bornet et Flahault, Revision des Nostocacées heterocystées, 228, 1888. Fig. 4 B

\text{HNFUSW}_OQ Trichomes straight, single or several, arranged parallel, with an indistinct mucilaginous
sheath. Cells discoid, 8-9 µ broad, 5-7 µ long, apical cells rounded. Heterocysts spherical or sub-spherical, 8-11 µ broad. Akinetes one or two on one or two sides of the heterocysts, sub-spherical, 11-16 µ broad, 12-16 µ long; epitospore smooth, yellowish brown.

*A. vaginicola* was reported from several regions such as Europe, Australia, New Zealand and also from lakes and rivers of India and Pakistan (Naz & al. 2004).

*A. variabilis* var. *ellipsospora* Fritsch, J. Indian Bot. Soc., 28: 142, 1949. Fig. 5 B

This name is currently regarded as a taxonomic synonym of *A. vaginicola* var. *ellipsospora* (Fritsch) Komárek et Anagnostidou

*A. vaginicola* var. *ellipsospora* was reported from paddy fields of India and Iran (Desikachary 1959, Shariatmadari & Riahi 2010).

11. *A. viguieri* Denis et Fremy, Bull. Soc. Linn. Normandie, Ser. 7, 6: 122, 1924. Fig. 6 A

Syn.: *S. CHIAIQIQ f. YIXIIIII* (Senis et Fremy) Komárek, Algolog. Studien, P. 124, 1958. planktic form of this species was also reported from aquatic ecosystems of Iran (Ramezanpoor 2004).

12. *Anabaena* sp. Fig. 6 B

Trichomes short, straight, single, dark blue-green; gelatinous sheath not present. Cells cylindrical, 3 µ broad, 6 µ long; apical cells rounded. Heterocysts intercalary, oblong with rounded ends, 4 µ broad, 7 µ long. Akinetes cylindrical, single, in both sides of heterocyst, 4 µ broad, 13 µ long.

*Anabaena* sp. was recorded Anabaena species in this study, following species are new records to Iran. $Anabaenopsis$ Bornet et Flahault, $Aphanizomenon$ (Carm.) Lagerh., $Filodictyon$ Rabenhorst ex Born et Flah, and $Vesicularia$ Klebahn had been reported from paddy fields of Gilan and Golestan provinces (Abrkar & Riahi 1995, Nowruz & Ahmadimoghadam 2006, Saadatnia & Riahi 2009), recorded Anabaena species in this study, following species are new records to Iran. $Aphanizomenopsis$ Bornet et Flahault, $Aphanizomenon$ N. L. Gardner, $Hormidium$ C. B. Rao, $Raphidiopsis$ Dixit and $Trichodesmus$ C. B. Rao.

ACKNOWLEDGMENTS

The authors gratefully acknowledge the financial support of University of Shahid Beheshti. Thanks are also due to Prof. Dr. Jiří Komárek and Dr. Soltani for assistance during the research.

www.SID.ir
Fig. 1. A. a- apical part of trichome, b- Part of trichomes with heterocysts and akinetes, c- mucilaginous envelop., B. a- part of trichomes with heterocysts and akinetes, b- apical part of trichome, c- akinetes (Scale: 10 μm).
Fig. 2. A. *Sphondylium*. a- apical part of trichome, b- part of trichomes with heterocysts and akinetes., B. *Sphondylium*. a- Terminal heterocyst, b- part of trichomes with heterocysts and akinetes., c- mucilaginous envelope (Scale: 10 μm).
Fig. 3. A. *S. smithii* a- apical part of trichome, b- part of trichomes with young akinetes., B. *S. trilobata* a- part of trichomes with heterocysts and akinetes., b- apical part of trichome (Scale: 10 μm).
Fig. 4. A. $\text{QEDHD sruiujhmv}$: a- part of trichomes with heterocysts and akinetes, b- apical part of trichome .
B. $\text{QEDHD srkljhf}$ a- apical part of trichome, b - part of trichomes with young akinetes, c- mucilaginous envelope (Scale: 10 μm).
Fig. 5. A. *Gelidiella violacea* a- apical part of trichome, b- part of trichomes with young akinetes., c- part of trichomes with heterocysts and akinet, d- mucilaginous envelope., B. *Gelidiella violacea* var. *Hosmeri* a-apical part of trichome, b-part of trichomes with heterocysts and akinetes (Scale: 10 μm).
Fig. 6. A. $Q D E D H Q D$ Y L JX L H U L: a- part of trichomes with heterocysts and akinetes, b- akinetes, c- apical part of trichome., B. Anabaena sp. a- part of trichomes with heterocysts and akinetes., b- apical part of trichome (Scale: 10 μm).
Fig. 7. a. $\text{QDUEQDO} \text{ VRFQGLQW} $  b. $\text{SKHJLJ} $  c. $\text{KHQWIL} $  d. $\text{YLOLHRO} $  e. $\text{RULQON} $  f. $\text{SURUHOM} $
Fig. 8. a. $QHEHOD$ var. $HO8M9SRID$ b. $YIJXIL$ c. $DP$ d. $sp.$ e. $IJUO8M9D$ f. $RRJDH$
REFERENCES


Komárek, J. 2010: Modern taxonomic revision of planktic nostocaceae cyanobacteria: a short review


Rangaswamy, G. 1996: Agricultural microbiology. -Asia publishing house, Bombay, p. 54-76.


