Egyptian Journal of Zoology (EJZ), Vol. 78: 41-60 (December, 2022) p-ISSN: 1110-6344
Publisher: The Zoological Society of A. R. Egypt e-ISSN: 2682-3160
DOI: 10.21608/ejz.2022.130389.1077

RESEARCH ARTICLE

NUMERICAL ANALYSIS OF THE MORPHOLOGICAL CHARACTERS OF SOME SPECIES OF AQUATIC MITES IN EGYPT

Somaia A. Ramadan; Asmaa N. Mustafa*

Zoology Department, Faculty of Science, Sohag University, Sohag, Egypt

Article History:
Received: 29 March 2022
Accepted: 1 May 2022

Published Online:
10 July 2022

Keywords:
Acari
Aquatic mites
Hierarchical clustering
Numerical taxonomy
PCA

***Correspondence:**
Asmaa Mustafa
Zoology Department
Faculty of Science
Sohag University
Sohag, Egypt
E-mail:
asmaa.ahmed1@science.sohag.edu.eg

ABSTRACT

The aim of this study was to determine the taxonomic position of some species of water mites, and explore the difference between the numerical taxonomy and the traditional morphological taxonomy for water mites. Based on hierarchical clustering analysis and principal component analysis (PCA), the numerical taxonomy of 17 species of water mites was carried out. These analyses were applied for 309 morphological characters of the present species. The results of the clustering analysis based on squared Euclidean distance showed that the 17 species of the water mites were divided into 10 Families in the cladogram namely Hydrozetidae, Malaconothridae, Unionicolidae, Tenuipalpidae, Tuckerellidae, Tetranychidae, Cheyletidae, Laelaptidae, Ascidae, and Dermanyssidae. The separation of these species depended on the highly-significant characters, which have high factor loading more than 1.0. The percentages of non-significant variations in the morphological characters were 51.90%, 18.45%, and 10.02% for two groups of water mite taxa with total variation equals 80.37%. In conclusion, the numerical analysis can confirm the traditional morphological taxonomy by using different analyses such as the cladistic analysis and PCA.

INTRODUCTION

Taxonomy is the science of the description and classification of organisms, essential in theoretical and applied Biology[1]. In the early 1960s, a group of statisticians and biologists introduced a new approach, known as numerical taxonomy[2]. The same authors suggested that the numerical taxonomy establishes classification of organisms based on their similarities. The numerical methods can be applied in many fields besides biological classification.

Much of the earlier systematic work on the terrestrial and aquatic mites was monophyletic. The taxonomists depended only on a few characters and specimens to differentiate taxa. A polyphyletic approach has been greatly facilitated by the advancement of cladistic and clusters methods, as well as phylogenetic relationships[3-6].

Many morphological characters of mites were analyzed and taxa were arranged using clustering methods based on overall similarity[7]. Some studies have been carried out on numerical taxonomy of mites[3,7-12]. Johnston and Kethley[8] investigated the numerical phenetic of the quill mites of the family Syringophilidae. Moss and Wojcik[3] studied the numerical taxonomic of the family Harpyrhynchidae. Other scientists investigated the numerical taxonomy of eriophyoid mites[9-11]. Sarwar *et al.*[12]

studied the numerical taxonomy of two mite species of the genus *Caloglyphus* Berlese from Pakistan. In addition, Pavan *et al*.[7] studied numerical taxonomy of 171 species of mites belonging to family Phytoseiidae.

On the other hand, molecular and morphological differentiations between some species of aquatic mites were carried out by Edwards and Dimock[13]. Functional and numerical responses of the predatory mite "*Neoseiulus longispinosus*" to the red spider mite "*Oligonychus coffeae*" infesting tea were reported by Rahman *et al*.[14].

Few studies were carried out on the water mites by numerical analysis, which required numerous morphological characters of larvae and adults[15-16]. In Egypt, Ramadan[17] studies the numerical taxonomic analysis on the taxa of 44 species of water mites. So, the present study aimed to demonstrate more investigations using cladistic (SPSS) and principal components (PCA) analyses on the adult water mites collected from different habitats of Assiut and Sohag Governorates in Egypt.

MATERIAL AND METHODS

Collection

Data for taxonomy study was collected from literatures[18-25]. The mite samples were collected from nine different freshwater bodies in Assiut and Sohag Governorates, Egypt. In Assiut Governorate, the adult mites were collected from three water canals called Magrur El- Assiuti, El-Sant, and Nabari El-kibleia[20-21]. In Sohag Governorate, the samples of mites were collected from four water canals, a pond, and River Nile. These water canals called Nagaa Hammadi, Morra, Arab Elkhalf canals, and an Arab pond[18-19]. Moreover, the mite samples were collected from mussel *Caelatura aegyptiaca*[22] and roots of the floating plant *Eichhorina crassipes* in River Nile[23-25].

Morphological analysis

The individuals of mite females from each species were randomly selected for morphological analysis. The morphological characters of the present study included the counts and ordered multi-state characters from all region of the body of mite species. Numerical analysis was carried out using two methods of analyses: cladistic[26] and principal components analysis (PCA)[27]. These analyses were based on 17 species of water mites (Operational Taxonomic Units, henceforth OUTs) described by 309 morphological characters coded 1-12 (Tables 1 and 2). The character state matrix entered into the SPSS program to construct the cladogram tree. The cladistic analysis distorts longer distances. The second analysis (PCA) used to calculate the distance matrix between components of the water mites. The morphological character states of the adult mites were determined by direct observations[22-25] and from published species[18-21].

RESULTS

In the present study, the higher taxa of water mites represent two suborders "Oribatida and Prostigmata", and order Mesostigmata, containing ten different aquatic families. Suborder Oribatida includes four species under two families namely Hydrozetidae and Malaconothridae, while suborder Prostigmata contains nine species represented five families called Unionicolidae, Tenuipalpidae, Tuckerellidae, Tetranychidae, and Cheyletidae. The order Mesostigmata includes four species classified under three families, Laelaptidae, Ascidae, and Dermanyssidae (Table 1). A numerical taxonomic analysis was applied to 309 morphometric characters from 17 species (Table 2).

Cladistic Analysis (SPSS)

In the present work, the SPSS cladistic analysis was applied to study the relationships within and between species of water mites in suborders, families, and genera. Figure "1" showed the cladogram tree produced by the previous analysis of each species using single linkage, which is a space contracting strategy meaning that growing clades increasingly attract their

Table 1: List of adult females of freshwater mites collected from different habitats in Sohag and Assiut Governorates, Egypt.

OUT Number	Species	Family	Sources	Habitat	Number of Adults
1	*Hydrozetes crassipes*	Hydrozetidae	Mustafa and Ramadan[25]	Roots of aquatic plant, *Eichhornia crassipes*	19
2	*Trimalaconothrus crassipes*	Malaconothridae	Ramadan *et al.*[23]		30
3	*Malaconothrus ramadani*		Ramadan *et al.*[24]		17
4	*Malaconothrus transversus*				13
5	*Unionicola aegyptiaca*	Unionicolidae	Ramadan *et al.*[22]	Freshwater mussel, *Caelatura aegyptiaca*	23
6	*Raoiella dicentralis*	Tenuipalpidae	Hussein and Mazen[20]	Three water canals	24
7	*Tuckerella bakeri*	Tuckerellidae			37
8	*Eutetranychus africanus*	Tetranychidae	Hussein and Soliman[18]	Four water canals, a pond, and River Nile	20
9	*Oligonychus partensis*				18
10	*Tetranychus arabicus*				26
11	*Hemicheyletia bakeri*	Cheyletidae	Hussein and Soliman[19]	Four water canals, a pond, and River Nile	3
12	*Hemicheyletia* sp.				5
13	*Eutogenes punctate*				3
14	*Ololaelaps chanti*	Laelaptidae	Hussein and Mazen[21]	Three water canals	65
15	*Hypoaspis reticulatus*				47
16	*Cheiroseius egypyicus*	Ascidae			39
17	*Pellonyssus evansi*	Dermanyssidae			33

nearest neighbor. The cladogram represents two main groups; the first group contains a mixture of the suborder Prostigmata and order Mesostigmata. The second group contains a mixture of the two suborders "Prostigmata and Oribatida" and order Mesostigmata. The Mesostigmata is a sister group to Prostigmata and close to Oribatida.

At the level of families and genera, Figure "1" showed that the cladogram consists of two main clades (groups 1 and 2) which can be distinguished as follows:

1- A clade of the first group consists of a mixture of three genera from two families. These families are Cheyletidae (Ch) and Dermanyssidae (De). The genera are *Hemicheyletia*, *Eutogenes*, and *Pellonyssus*.
2- A clade of the second group is sub-divided into two subgroups: the first subgroup has a mixture of genera from seven families namely Unionicolidae (Un), Tenuipalpidae (Te), Tuckerellidae (Tu), Tetranychidae (Tet), Laelaptidae (La), Ascidae (As), and Hydrozetidae (Hy). This subgroup contains ten genera such as, *Unionicola*, *Raoiella, Tuckerella*, *Eutetranychus*, *Oligonychus, Tetranychus, Ololaelaps, Hypoaspis, Cheiroseius*, and *Hydrozetes.* On the other hand, the second subgroup has a mixture of two genera belonging to family Malaconothridae (Ma), such as *Trimalaconothrus* and *Malaconothrus*.

Table 2: Characters and character states used in morphometric analysis of freshwater mites.

Character	Character state	Code	Character	Character state	Code	Character	Character state	Code
1- Color	Yellowish brown	1	9- Types of setae	Pilose	1	22- Exobothridial setae	Absent	1
	Yellow	2					Present	2
	Pale yellow	3		Simple	2	23- No. of setae	2 Setae	1
	Dark red	4		Pilose+ Simple	3		6 Setae	2
	Yellowish green	5	10- Decoration	Punctuate	1		Absent	3
	Light-brown	6		Coarse pits	2	24- Lamellae	Absent	1
	Brown	7		Absent	3		Present	2
	Dark yellow	8	Rostrum	Absent	1	25- Number	Absent	1
	Reddish-brown	9	11- Shield	Present	2		2	2
2- Body Shape	Elongated	1	12- S-shape	Absent	1	26- Prodorsal ridges	Absent	1
							Present	2
	Semi-circular	2		Present	2	27- No. of ridges	Absent	1
	Oval	3					4	2
3- Decoration	Rounded pits	1	13- No. of setae	6 Setae	1	28- Tricho-bothria	Absent	1
	Coarse pits	2		8 Setae	2		Present	2
	Punctuate	3		Absent	3	29- Number	Absent	1
	Crescentic-like	4	14- Size of setae	Long	1		2	2
	Smooth	5				30- Lateral portions	Absent	1
	Network	6		Short	2		Present	2
	Scale-shaped	7		Long+ Short	3	31- Lateral carinae	Absent	1
	Arch-shaped	8		Absent	4		Present	2
	Irregular striae	9	15- Types of setae	Pilose	1	32- No. of carinae	2	1
	Micro-foveolate	10		Simple	2		4	2
	Absent	11		Pilose+ Simple	3		Absent	3
4- G.R.O	Absent	1		Absent	4	33- No. of setae	4 Setae	1
	Present	2	16- Rostral setae	Absent	1		Absent	2
5- No. G.R.O	2	1		Present	2	34- Postero-lateral	Absent	1
	6	2	17- No. of setae	2 Setae	1		Present	2
	Absent	3		4 Setae	2	35- Shape	Triangular	1
Prodorsum 6- Shape	Polygonal	1		Absent	3		Absent	2
	Triangular	2	18- Lamellar setae	Absent	1	Chelicerae	Dentate	1
	Absent	3		Present	2	36- Shape	Toothed	2
7- No. of setae	8 Setae	1	19- No. of setae	2 Setae	1		Needle+ minute chela	3
	12 Setae	2		4 Setae	2		Whip-like	4
	Absent	3	20- Inter-lamellar setae	Absent	1		Needle	5
8- Size of setae	Long	1		Present	2	37- No. of segments*	2	1
	Short	2	21- No. of setae	2 Setae	1		3	2
	Long+ Short	3		4 Setae	2	38- Setae	Absent	1
				Absent	3		Present	2

Table 2 Continuous

Character	Character state	Code	Character	Character state	Code	Character	Character state	Code
39- No. of setae	2	1	53- No. of setae	Absent	1		1.0 Seta	4
	3	2		1.0 Seta	2		4 Setae	5
	Absent	3		4 Setae	3		Absent	6
40- Types of setae	Simple	1		5 Setae	4	62- Size of setae	Short	1
	Pilose	2		3 Setae	5		Long	2
	Absent	3		2 Setae	6		Long+ Short	3
41- Size of setae	Tiny	1	54- Size of setae	Absent	1		Moderate	4
	Long	2		Long	2		Absent	5
	Absent	3		Moderate	3	63- Types of setae*	Simple	1
42- Trägårdh's organ	Absent	1	55- Types of setae	Absent	1		Pilose	2
	Present	2		Pilose	2		Pilose+ Simple	3
Pedipalp 43- Shape	Straight	1		Simple	3		Serrate	4
	Curved	2		Pilose+ Simple	4		Absent	5
	Elongate	3		Serrate	5	64- Solenidia*****	Absent	1
44- Direction	Inward	1		Spatulate	6		Present	2
	Anterior	2	P-3 56- Shape	Rect-angular	1	65- Number	Absent	1
45- No. of segments	5	1		Elongated	2		1	2
	3	2		Cylindrical	3	66- Processes	Absent	1
	2	3		Slender	4		Present	2
	4	4		Square	5	67- Number	Absent	1
46- Simple setae	Absent	1		Absent	6		2	2
	Present	2	57- No. of setae*****	1.0 Seta	1	68- Setae	Absent	1
47- Pilose setae	Absent	1		2 Setae	2		2	2
	Present	2		3 Setae	3	69- No. of tibial claw	Absent	1
P-1 48-Shape	Rectangular	1		4 Setae	4		1	2
	Triangular	2		Absent	5	P-5 70- Shape	Circular	1
	Slender	3	58- Size of setae	Short	1		Semi-circular	2
	Elongated	4		Long	2		Conical	3
	Trapezoidal	5		Long+ Short	3		Slender	4
	Absent	6		Moderate	4	71- No. of setae	3 Setae	1
49- No. of setae	Absent	1		Absent	5		6 Setae	2
	1.0 Seta	2	59- Types of setae	Simple	1		4 Setae	3
50- Size of setae	Absent	1		Pilose	2		2 Setae	4
	Short	2		Serrate	3		10 Setae	5
51-Types of setae	Absent	1		Absent	4		1.0 Seta	6
	Simple	2	P-4 60- Shape	Rect-angular	1		9 Setae	7
P-2 52- Shape	Triangular	1		Elongated	2		Absent	8
	Trapezoidal	2		Slender	3	72- Size of setae	Tiny	1
	Cylindrical	3		Square	4		Short	2
	Slender	4		Triangular	5		Moderate	3
	Rectangular	5	61- No. of setae	2 Setae	1		Long	4
	Elongated	6		3 Setae	2		Absent	5
	Absent	7		5 Setae	3			

Table 2 Continuous

Character	Character state	Code	Character	Character state	Code	Character	Character state	Code
73-Types of setae	Simple	1	88- Number	Absent	1	103- Lenticulus	Absent	1
	Pilose	2		1	2		Present	2
	Sickle	3		7	3	104- No. of setae	26 Setae	1
	Simple+ Pilose	4	89- Humeral	Absent	1		30 Setae	2
	Absent	5		Present	2		18 Setae	3
74- No. of solenidia	7	1	90- Number	Absent	1		28 Setae	4
	9	2		4	2		44 Setae	5
	1	3	91- Pro-podosoma	Absent	1		78 Setae	6
	Absent	4		Present	2		80 Setae	7
75- Clawlets	Absent	1	92- Number	Absent	1		84 Setae	8
	Present	2		1	2		82 Setae	9
76- Number	Absent	1	93- Hyster-osoma	Absent	1	105- Types of setae	Pilose	1
	2	2		Present	2		Pilose+ Simple	2
	1	3	94- Number	Absent	1		Simple	3
77- Palpal apotele	Absent	1		1	2		Rod-like	4
	3 Tines	2	95- Dorsal shields	Absent	1		Fan-shaped	5
	2 Tines	3		Present	2		Plumose	6
Dorsal side	Oval	1	96- Number	Absent	1		Serrate	7
78- Shape	Rectangular	2		1	2		Feathered	8
79- Plates	Absent	1	97- Dorsal folds	Absent	1	106- Size of setae	Long	1
	Present	2		Present	2		Short	2
80- Number*	Absent	1	98- Decoration	Rounded pits	1		Moderate	3
	6	2		Coarse pits	2		Long+ Moderate	4
	4	3		Punctuate	3	107- Gland openings	Absent	1
	2	4		Smooth	4		Present	2
	1	5		Network	5	108- Number	Absent	1
	11	6		Scale	6		2	2
81-Central*	Absent	1		Arch	7	109- Dorso-phragmata	Absent	1
	Present	2		Irregular striae	8		Present	2
82- Number	Absent	1		Micro-foveolate	9	110- Cristae	Absent	1
	1	2		Absent	10		Present	2
83- Paracentral	Absent	1	99- Lateral margins	Parallel	1	111- Stigmata	Absent	1
	Present	2		Zig-zag	2		Present	2
84- Number*	Absent	1	100-No. of lyrifissures	2	1	112- No. of stigmata	Absent	1
	2	2		4	2		4	2
85- Lateral*	Absent	1		6	3	113- Small plates	Absent	1
	Present	2		Absent	4		Present	2
86- Number*	Absent	1	101- Eyes	Absent	1	114- Number	Absent	1
	2	2		Present	2		4	2
87- Opis-thosoma	Absent	1	102- No. of eyes	Absent	1		2	3
	Present	2		4	2	115- Platelets	Absent	1
				2	3		Present	2

Table 2 Continuous

Character	Character state	Code	Character	Character state	Code	Character	Character state	Code
116- No. of platelets	Absent	1	Lateral	Absent	1	Propodo-soma	Absent	1
	4	2	132- Decoration	Rounded	2		Coarse pits	2
117-Y-shape	Absent	1	133- Shape	Trape-zoidal	1	145- Decoration	Punctuate	3
	Present	2		Triangular	2	146- Shape	Absent	1
118- Cuticle	Unstriated	1		Absent	3		Triangle	2
	Striated	2	134- No. of setae	Absent	1		Trapezoid	3
119- Processes	Absent	1		14 Setae	2	147- No. of setae	Absent	1
	Present	2		2 Setae	3		12 Setae	2
120- Number	Absent	1	135- Size of setae	Long+ Short	1		20 Setae	3
	5	2		Moderate	2		24 Setae	4
Plates	Elongated	1		Absent	3	148 - Size of setae	Absent	1
Central	Oval	2	136- Type of setae	Pilose+ Simple	1		Short	2
121- Shape	Absent	3		Simple	2		Moderate	3
122- Decoration	Rounded	1		Absent	3		Long	4
	Coarse pits	2	Opistho-soma	Absent	1	149- Type of setae	Absent	1
	Absent	3		Punctuate	2		Simple	2
			137- Decoration					
123- Crescentic decoration	Absent	1	138- Shape	Semi-circular	1		Serrate	3
	Present	2		Trape-zoidal	2		Pilose	4
124- No. of setae*	Absent	1		Rect-angular	3	Hystero-somal	Absent	1
	8 Setae	2		Absent	4	150- Decoration	Coarse pits	2
125- Types of setae	Pilose	1	139- No. of setae	4 Setae	1		Punctuate	3
	Simple	2		2 Setae	2	151- Shape	Absent	1
	Absent	3		12 Setae	3		Triangular	2
126- Size of setae	Short	1		Absent	4		Trapezoid	3
	Long	2	140- Size of setae	Short	1	152- No. of setae	Absent	1
	Absent	3		Long+ Short	2		8 Setae	2
Paracentral	Elongated	1		Long	3		10 Setae	3
127- Shape	Absent	2		Absent	4		20 Setae	4
128- Decoration	Rounded	1	141- Type of setae	Pilose	1	153- Size of setae	Absent	1
	Absent	2		Pilose+ Simple	2		Short	2
129- No. of setae	4 Setae	1		Simple	3		Moderate	3
	Absent	2		Absent	4		Long	4
130-Size of setae	Short	1	Humeral	Absent	1	154- Type of setae	Absent	1
	Long	2	142- No. setae	2 Setae	2		Simple	2
	Absent	3	143- Size of setae	Absent	1		Serrate	3
131- Type of setae	Pilose	1		Long	2		Pilose	4
	Simple	2	144- Type of setae	Absent	1	Dorsal shields	Absent	1
	Absent	3		Simple	2	155- Decoration	Network	2

Table 2 Continuous

Character	Character state	Code	Character	Character state	Code	Character	Character state	Code
	Scale	3	171- Size of 4th	Complete	1	181- No. of spines	Absent	1
	Arch	4		Incomplete	2		12	2
156- Shape	Absent	1		Absent	3	182- Processes	Absent	1
	Oval	2	172- Shape of 5th, 6th	Arch-like	1		Present	2
157- No. of setae	Absent	1		Absent	2	183- Ventral processes	Absent	1
	78 Setae	2	173- Size of 5th, 6th	Complete	1		Present	2
	80 Setae	3		Incomplete	2	184- Number	Absent	1
	84 Setae	4		Absent	3		6	2
158- Size of setae	Absent	1	Ventral side	Rounded	1	185- Ventral lyrifissures	Absent	1
	Short	2	174- Decoration	Coarse pits	2		Present	2
	Moderate	3		Network	3	186- Number	Absent	1
	Long	4		Irregular striae	4		4	2
159- Type of setae	Absent	1		Absent	5		2	3
	Simple	2	Plates	Absent	1	187-Glan-dularia	Absent	1
Dorsal folds	Thin	1	175- Number	5 plates	2		Present	2
160-Width*	Thick	2		6 plates	3	188- Number	Absent	1
	Absent	3		4 plates	4		4	2
161- Long folds	Absent	1		3 plates	5	189- Tri-tosternum	Absent	1
	Present	2	Platelets	Absent	1		Present	2
162- Number	Absent	1	176- Number	2	2	Tritos-ternum	Absent	1
	2	2		4	3		Triangular	2
163-Shape*	Oblique	1	177- Shape	Absent	1	190- Shape of base	Elongated	3
	Absent	2		Oval	2	191- No. of laciniae	Absent	1
164- Tran. folds*	Absent	1		Triangular	3		2	2
	Present	2	178- Ventral folds	Absent	1	192- Shape of laciniae	Absent	1
165- Number*	6	1		Present	2		Feathered	2
	7	2	179- No. of setae	20 Setae	1	193- Size of laciniae*	Absent	1
	Absent	3		26 Setae	2		Long	2
166- Shape of 1st, 2nd	Straight	1		42 Setae	3	Plates	Absent	1
	Absent	2		8 Setae	4	194- Presternal	Present	2
167- Size of 1st, 2nd	Complete	1		10 Setae	5	195- Sternal*	Absent	1
	Incomplete	2		18 Setae	6		Present	2
	Absent	3		22 Setae	7	196- Parapodal	Absent	1
168-Shape of 3rd	W-like	1		24 Setae	8		Present	2
	Absent	2		33 Setae	9	197- Metapodal	Absent	1
169- Size of 3rd	Complete	1		32 Setae	10		Present	2
	Incomplete	2		57 Setae	11	198- Meta-sternal	Absent	1
	Absent	3		39 Setae	12		Present	2
170- Shape of 4th	Semi-circular	1	Epimerae	Absent	1	Presternal	Absent	1
	Absent	2	180- Spines	Present	2	199- Number	2	2

Table 2 Continuous

Character	Character state	Code	Character	Character state	Code	Character	Character state	Code
200- Decoration	Absent	1	Epimera I	2	1	230- Shape of 1st*	Oblique	1
	Trans.striae	2	218- Number	3	2		Laterally oblique	2
201- Shape	Absent	1		Absent	3		Absent	3
	Oval	2	219- No. of setae	2 Setae	1	231- Shape of 2nd, 3rd	W-like	1
Sternal	Absent	1		6 Setae	2		Oblique	2
202- Number	1	2		10 Setae	3		Absent	3
203- Decoration	Absent	1		4 Setae	4	232- Shape of 4th	Inverted arch	1
	Network	2		Absent	5		Oblique	2
204- Shape	Absent	1	Epimera II	2	1		Absent	3
	Quadratic	2	220- Number	3	2	233- Shape of 5th, 6th	Laterally oblique	1
	Triangular	3		Absent	3		Absent	2
205- No. of setae	Absent	1	221- No. of setae	2 Setae	1	234- Tran. folds	Absent	1
	6 Setae	2		4 Setae	2		Present	2
206- Size of setae	Absent	1		6 Setae	3	235- Number	Absent	1
	Short	2		Absent	4		1	2
	Moderate	3	Epimera III	2	1	236- Shape	Semi-circular	1
207- Type of setae	Absent	1	222- Number	3	2		Absent	2
	Simple	2		Absent	3	237- Cir-cumpedal carinae	Absent	1
208- Lyri-fissures*	Absent	1		4 Setae	1		Present	2
	4	2	223- No. of setae	6 Setae	2	Genital area	Dorsal	1
Parapodal	Absent	1		8 Setae	3		Ventral	2
209- Number*						238- Genital opening		
	1	2		Absent	4	239- Shape	Elongated	1
210- Shape	Absent	1	Epimera IV	2	1		Transverse	2
	Triangular	2		3	2		Absent	3
Metapodal	Absent	1	224- Number	Absent	3	Genital plates	2	1
211- Number	1	2	225- No. of setae*	4 Setae	1	240- Number	4	2
	2	3		6 Setae	2		Absent	3
212- Shape	Absent	1		12 Setae	3	241- Shape	Elongated	1
	Elongated	2		2 Setae	4		Semi-circular	2
Metasternal	Absent	1		Absent	5		Semi-oval	3
213- Number	1	2	Ventral side		1		Absent	4
214- Shape	Absent	1	226- Types of setae	Pilose				
				Simple	2	242- No. of setae	8 Setae	1
	Spindle	2	227- Size of setae	Short	1		10 Setae	2
	Oval	3		Long	2		12 Setae	3
215- No. of setae	Absent	1		Moderate	3		16 Setae	4
	1.0 Seta	2	228- Long. folds	Absent	1		4 Setae	5
	2 Setae	3		Present	2		Absent	6
216- Size of setae	Absent	1	229- Number*	4	1			
	Short	2		7	2			
217- Type of setae	Absent	1		Absent	3			
	Simple	2						

Table 2 Continuous

Character	Character state	Code	Character	Character state	Code	Character	Character state	Code
243- Size of setae	Short	1	257- De-coration*	Absent	1		Triangular	4
	Long	2		Network	2		Absent	5
	Moderate	3	258- No. of setae*	Absent	1	272- Setae	Absent	1
	Short+Long	4		15 Setae	2		Present	2
	Absent	5	259- Size of setae*	Absent	1	273- No. of setae	Absent	1
244- Type of setae	Simple	1		Short	2		2 Setae	2
	Pilose	2		Moderate	3		8 Setae	3
	Absent	3	260- Type of setae*	Absent	1		4 Setae	4
Aggenital plates	Absent	1		Simple	2		6 Setae	5
245- Plates	Present	2	Genito-ventral				3 Setae	6
				Absent	1			
246- Number	2	1	261- Plates	Present	2	274- Anal valves	Absent	1
	4	2	262- Shape	Absent	1		Present	2
	Absent	3		Tongue-like	2	275- Number	Absent	1
247- Shape	Pear-like	1		Triangular	3		2	2
	Semi-circular	2	263- De-coration*	Absent	1	Adanal plates	Elongated	1
	Absent	3		Striae	2		Oval	2
248- Decoration	Rounded pits	1	264- No. of setae*	Absent	1	276- Shape	Absent	3
	Coarse pits	2		2 Setae	2	277- No. of setae	6 Setae	1
	Absent	3	265- Size of setae*	Absent	1		8 Setae	2
249- No. of genital discs	2	1		Short	2		2 Setae	3
	6	2		Moderate	3		4 Setae	4
	Absent	3	266- Type of setae	Absent	1		Absent	5
Pregenital plates	Absent	1		Simple	2	278- Decoration	Rounded	1
250- Plates	Present	2	Anal area				Coarse pits	2
			267- Anal opening	Dorsal	1			
251- Number	2	1		Ventral	2		Network	3
	Absent	2	268- Shape	Elongated	1		Absent	4
252- Shape	Triangular	1		Oval	2	279- Lyri-fissures	Absent	1
	Absent	2		Absent	3		Present	2
253- Genital acetabulae	Absent	1	Anal plates	Absent	1	280- Number of lyrifissures	2	1
	Present	2	269- Plates	Present	2		Absent	2
254- Number*	Absent	1	270- Number	2	1	281- Size of setae	Short	1
	50	2		4	2		Moderate	2
Genito-ventro-anal 255- Plates*	Absent	1		1	3		Absent	3
	Present	2		Absent	4	282- Type of setae	Simple	1
256- Number*	Absent	1	271- Shape	Elongated	1		Absent	2
	1	2		Circular	2			
				Pear-like	3			

Table 2 Continuous

Character	Character state	Code	Character	Character state	Code
Ventri-anal	Absent	1	295- Solenidia	Absent	1
283- Plates	Present	2		Present	2
284- Shape	Absent	1	296- Pilose setae	Absent	1
	Triangular	2		Present	2
285- No. of setae	Absent	1	297- Simple setae	Absent	1
	11 Setae	2		Present	2
286- Size of setae	Absent	1	298- Quill setae	Absent	1
	Short	2		Present	2
	Moderate	3	299- Club-like setae	Absent	1
287- Type of setae	Simple	1		Present	2
	Absent	2	300- Feather-like setae	Absent	1
Lateral regions of ventral side	4 Setae	1		Present	2
	8 Setae	2	301- Swimming hairs	Absent	1
288- No. of setae	Absent	3		Present	2
	Long+ Short	1	302-Finger-like projection setae	Absent	1
289- Size of setae	Long	2		Present	2
	Moderate	3	303- Teeth of first finger-like setae	5 teeth	1
	Absent	4		8 teeth	2
290- Type of setae	Simple	1		Absent	3
	Pilose+Simple	2	304- Teeth of second finger-like setae	4 teeth	1
	Pilose	3		5 teeth	2
	Absent	4		Absent	3
	5	1	305- Palmate setae	Absent	1
Legs (I- IV)	6	2		Present	2
291- No. of leg segment	8	3	306- Tenent hairs	Absent	1
	9	4		Present	2
	8-9	5	307- Leg empodium	Absent	1
292- Spines of coxa II	Absent	1		Present	2
	Present	2	308- Flagelliform setae	Absent	1
	1	1		Present	2
293- No. of claws	3	2	309- Sensory setae	Absent	1
	2	3		Present	2
	Absent	4			
294- Types of claws	Simple	1			
	Hook-like	2			
	Absent	3			

G.R.O: granulated rounded organs, No.: number, *****: highly significant characters that have high factor loading more than 1.0

At the level of species, there are separations within the present cladogram between species from different genera cladisting within other genera such as *Trimalaconothrus* (2) within *Malaconothrus* (3-4) and *Unionicola* (5) within suborder Prostigmata (6-10) based on their characters and character states. Two species, *Hydrozetes* (1) and *Pellonyssus* (17) are located between two different clades (Figure 1). The remaining species from different genera cladist within other genera without separation.

On the other hand, Figure "1" showed some degree of similarities among species within some genera as follows: firstly, a clade of OUTs (3-4) as *Malaconothrus ramadani* and *Malaconothrus transversus*, together, based mainly on presence of dorsal and ventral folds. Secondly, a clade of

OUTs (6-10) as *Raoiella dicentralis, Tuckerella bakeri, Eutetranychus africanus, Oligonychus partensis*, and *Tetranychus arabicus*, based on whip-like chelicerae and number of each cheliceral segments. Thirdly, a clade of OUTs (11-13) as *Hemicheyletia bakeri*, *Hemicheyletia* sp., and *Eutogenes punctate*, based on presence of sickle-like and comb-like setae on palpal tarsus setae, needle-like chelicerae, presence of noto-gastral propodosomal and hysterosomal plates and spatulate serrate notogastral setae. Finally, a clade of OUTs (14-16) as *Ololaelaps chanti, Hypoaspis reticulatus*, and *Cheiroseius egypyicus*, based on presence of palpal apotele, ventral tritosternum, and ventral plates.

The highest percentages of similarity for the morphological characters between some different species from different genera are recorded as follows: *Malaconothrus ramadani* and *Malaconothrus transversus* (94%), *Cheiroseius egypyicus* and *Ololaelaps chanti* (86%), *Eutetranychus africanus* and *Tetranychus arabicus* (96%), *Raoiella dicentralis* and *Tuckerella bakeri* (94%), and *Hemicheyletia bakeri* and *Hemicheyletia* sp. (95%).

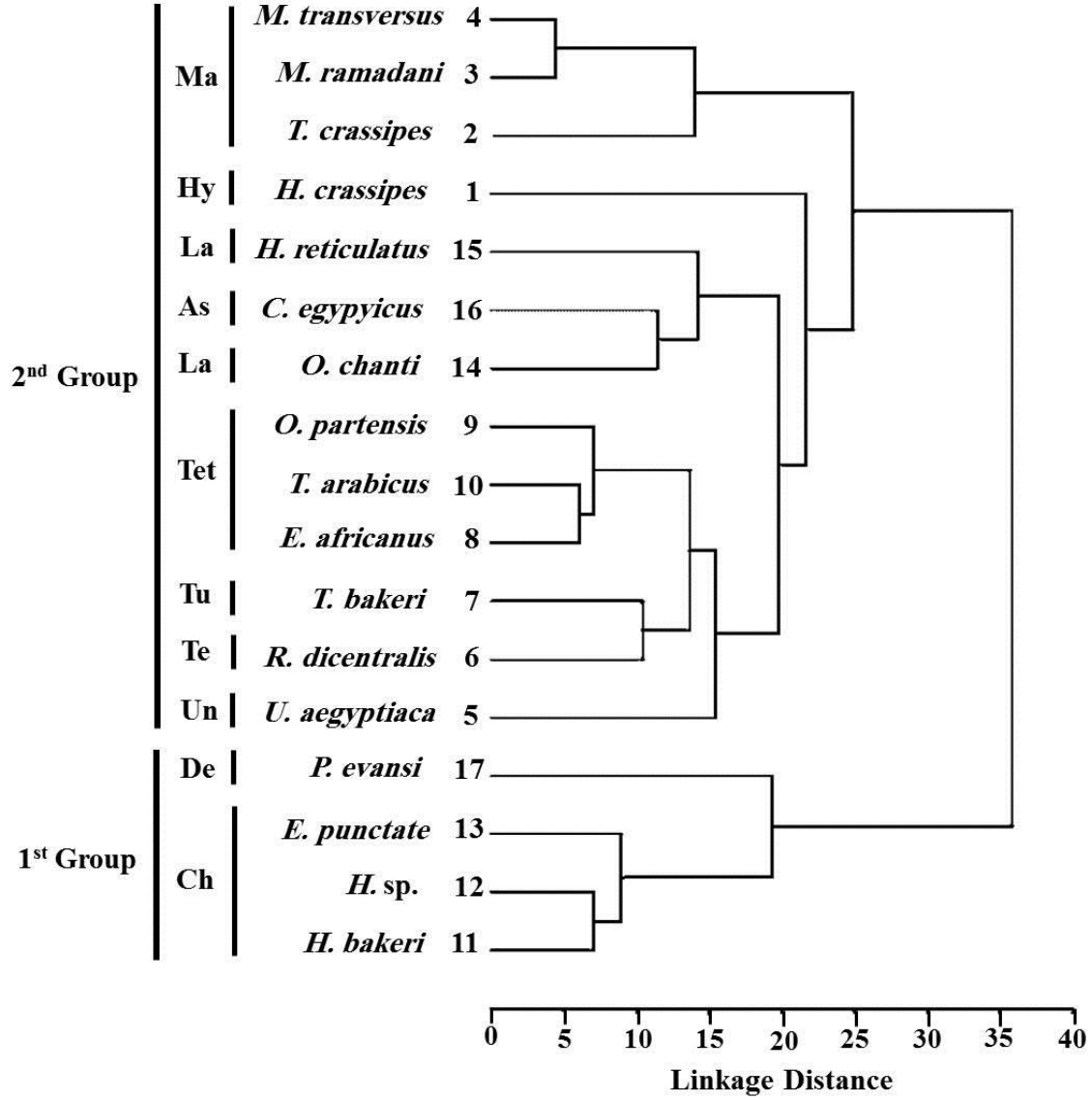

Figure 1: Cladogram tree of the 17 species of water mites using SPSS analysis. Ma: Malaconothridae, Hy: Hydrozetidae, La: Laelaptidae, As: Ascidae, Tet: Tetranychidae, Tu: Tuckerellidae, Te: Tenuipalpidae, Un: Unionicolidae, De: Dermanyssidae, Ch: Cheyletidae.

Principal Components Analysis (PCA)

The PCA was carried out for morphometric variations of 17 species, which based on 309 morphometric characters. The PCA reflects which characters are important on the axes and indicated the significant characters based on the highest factor loading. Table "3" showed a highly significant factor loading (>1.0) for the present 17 OUTs of mite taxa. The plot of 17 OUTs on the first and second principal components axes is shown in Figure "2". The plot of factors 1/2 together show two groups as described in the previous cladogram. The separation of the two groups depending on the highly significant characters that have high factor loading more than 1.0 that are labeled (*****) in Tables (2 and 3). On the other hand, the percentage of non-significant variations in the morphological characters for the respective two groups are 51.9%, 18.45%, and 10.02%, which are pooled in a total variation that equals 80.37% (Table 3).

DISCUSSION

In the present study, 309 morphological characters were used for the segregation between 17 species of aquatic mites, and statistical methodology was carried out. The present aquatic mites occurred in different habitats. The present cladogram tree showed that the taxa of water mites were distinguished into two main groups containing the two suborders "Oribatida and Prostigmata" and order Mesostigmata. Moss and Wojcik[3] recorded two groups of 15 species of prostigmatid mites. Edwards and Dimock[13] recorded two groups of water mites belonging to suborder Prostigmata, six populations of *Unionicola foili* and four populations of *Unionicola formosa*. Ramadan[17] recorded three main groups for 44 species of water mites included the two suborders "Prostigmata and Astigmata" and order Mesostigmata. Pavan Kumar *et al*.[7] recorded three isolated groups for 171 species of mesostigmatid mites.

In the present work, the Mesostigmata is a sister group to Prostigmata and close to Oribatida. Ramadan[17] indicated that the Prostigmata was a sister group to the Mesostigmata, but Astigmata is closer to the former. Smith and Cook[28] considered the water mites as a sister group to the terrestrial Parasitengona and based their hypothesis on the fact that parasitengones are derived from aquatic ones.

In the present study, the cladogram of mite taxa at the level of families and genera within the Mesostigmata was divided into two clades. The interspersion among families and their genera within the water mites revealed a polyphyletic origin, where the species of Mesostigmata are interspersed within those of Prostigmata. OConnor[4] suggested that the terrestrial Prostigmata and Astigmata gave monophyletic and paraphyletic groups, respectively. Avanzati *et al*.[29] described three clades within the cladogram of the oribatid mites. Hong and Zhang[11] reported that cladograms of terrestrial mite taxa at generic level of family Eriophyidae were monophyletic and divided into three clades. Lindquist[30] represented cladograms of terrestrial taxa within the Prostigmata and divided it into three clades and shifted Bdellidae and Halacaridae to the base of the cladogram. Dabert[6] concluded that the species and genera within the terrestrial Astigmata were placed in a monophyletic clade. Ramadan[17] indicated that the water mites have a polyphyletic assemblage of taxa because the species of Prostigtmata are interspersed within those of Astigmata and Mesostimgata.

In the present investigation, the percentage of similarity between some different species from different genera is ranged from 86% to 96%. Sarwar *et al*.[12] indicated that the highest percentage of similarity between some species of genus *Caloglyphus* was ranged from 80% to 92%.

In the present study, the PCA revealed two groups of taxa having high factor loading (>1.0) of 17 OUTs mite taxa. The percentages of the morphological variations within the components recorded 51.9%, 18.45%, and 10.02% for the first, second, and third axes, respectively. Moss and

Table 3: Morphological characters showing the highest factor loadings on the first three components (PCA).

No.	Principal components (PCs) Factor loading			No.	Principal components (PCs) Factor loading			No.	Principal components (PCs) Factor loading		
	PC 1	PC 2	PC 3		PC 1	PC 2	PC 3		PC 1	PC 2	PC 3
1	0.03	0.1	0.12	39	– 0.02	– 0.05	0.02	77	0.01	0.05	0.11
2	0.03	0.07	0.01	40	0.03	0.09	– 0.03	78	– 0.01	– 0.05	0.01
3	– 0.09	0.4	– 0.17	41	0.03	0.09	– 0.03	79	0.02	0.01	0.05
4	– 0.01	– 0.05	0.01	42	– 0.01	– 0.01	0.01	80	0.03	– 0.07	0.23
5	0.02	0.07	– 0.02	43	0.03	0.09	– 0.02	81	– 0.01	– 0.02	– 0.01
6	0.03	0.09	– 0.03	44	0.01	– 0.01	0.01	82	– 0.01	– 0.02	– 0.01
7	0.03	0.08	– 0.03	45	0.05	0.04	– 0.18	83	– 0.01	– 0.02	0.01
8	0.02	0.05	– 0.02	46	0	0	0	84	– 0.01	– 0.02	0.01
9	0.02	0.05	– 0.02	47	0.01	– 0.06	– 0.01	85	– 0.01	– 0.02	– 0.01
10	0.02	0.06	– 0.02	48	0.08	0.1	– 0.28	86	– 0.01	– 0.02	– 0.01
11	– 0.01	– 0.05	0.01	49	0.01	0.01	0.02	87	– 0.01	– 0.02	0.01
12	– 0.01	– 0.05	0.01	50	0.01	0.01	0.02	88	– 0.02	– 0.02	0.01
13	0.02	0.05	– 0.02	51	0.01	0.01	0.02	89	– 0.01	– 0.01	0.01
14	0.02	0.05	– 0.02	52	0.06	0.17	– 0.08	90	– 0.01	– 0.01	0.01
15	0.02	0.05	– 0.02	53	0.07	0.01	0.04	91	0.04	– 0.01	– 0.01
16	– 0.02	– 0.05	0.02	54	0.04	0.03	0.01	92	0.04	– 0.01	– 0.01
17	0.03	0.09	– 0.03	55	0.08	0.02	– 0.05	93	0.04	– 0.01	– 0.01
18	– 0.02	– 0.05	0.02	56	0.1	0.03	– 0.02	94	0.04	– 0.01	– 0.01
19	0.03	0.09	– 0.03	57	0.02	0.11	0.09	95	– 0.01	0.02	0.05
20	– 0.02	– 0.05	0.02	58	0.01	0.11	0.08	96	– 0.01	0.02	0.05
21	0.03	0.09	– 0.03	59	0.04	0.02	– 0.02	97	– 0.01	– 0.03	0.01
22	– 0.02	– 0.05	0.02	60	0.05	0.1	– 0.05	98	– 0.08	0.32	– 0.17
23	0.03	0.08	– 0.03	61	0.01	0.09	0.11	99	– 0.01	– 0.02	0.01
24	– 0.01	– 0.01	0.01	62	– 0.05	0.02	0.05	100	0.03	0.09	– 0.03
25	– 0.01	– 0.01	0.01	63	0.01	– 0.07	0.08	101	0.01	0.02	– 0.07
26	– 0.01	– 0.01	0.01	64	– 0.01	– 0.02	– 0.01	102	0.02	0.03	– 0.12
27	– 0.01	– 0.01	0.01	65	– 0.01	– 0.02	– 0.01	103	– 0.01	– 0.01	0.01
28	– 0.01	– 0.01	0.01	66	– 0.01	0.01	– 0.01	104	0.09	0.16	0.27
29	– 0.01	– 0.01	0.01	67	– 0.01	0.01	– 0.01	105	0.14	0.06	– 0.04
30	– 0.01	– 0.05	0.01	68	– 0.01	0.01	– 0.01	106	0.06	– 0.02	0.08
31	– 0.01	– 0.05	0.01	69	0.02	0.01	– 0.06	107	– 0.01	– 0.01	0.01
32	0.02	0.09	– 0.02	70	– 0.01	0.07	0.01	108	– 0.01	– 0.01	0.01
33	0.01	0.02	– 0.01	71	– 0.02	0.15	0.06	109	– 0.01	– 0.01	0.01
34	– 0.01	– 0.03	0.01	72	0.03	0.06	0.04	110	– 0.01	– 0.01	0.01
35	0.01	0.03	– 0.01	73	0.04	0.01	0.07	111	– 0.01	0.01	– 0.01
36	0.08	0.05	– 0.2	74	0.03	0.1	– 0.03	112	– 0.01	0.01	– 0.01
37	– 0.02	– 0.02	0.07	75	– 0.01	0.02	– 0.02	113	0.02	– 0.01	– 0.02
38	0.03	0.09	– 0.03	76	– 0.02	0.03	– 0.04	114	0.03	– 0.02	– 0.03

Table 3 Continuous

No.	Principal components (PCs) Factor loading			No.	Principal components (PCs) Factor loading			No.	Principal components (PCs) Factor loading		
	PC 1	PC 2	PC 3		PC 1	PC 2	PC 3		PC 1	PC 2	PC 3
115	– 0.01	0.01	– 0.01	154	0.06	– 0.02	– 0.02	193	0.01	0.03	0.06
116	– 0.01	0.01	– 0.01	155	– 0.02	0.05	0.1	194	– 0.01	0.01	0.02
117	– 0.01	0.01	– 0.01	156	– 0.01	0.02	0.05	195	0.01	0.03	0.06
118	0.03	– 0.01	– 0.04	157	– 0.02	0.05	0.1	196	– 0.01	0.01	0.02
119	– 0.01	– 0.02	0.01	158	– 0.02	0.05	0.12	197	– 0.01	0.02	0.04
120	– 0.01	– 0.02	0.01	159	– 0.01	0.02	0.05	198	– 0.01	0.02	0.03
121	0.01	0.03	0.01	160	5.71*****	1.13*****	2.91*****	199	– 0.01	0.02	0.04
122	0.01	0.03	– 0.01	161	– 0.01	– 0.02	0.01	200	– 0.01	0.02	0.04
123	0	0	0	162	– 0.01	– 0.02	0.01	201	– 0.01	0.02	0.04
124	– 0.01	– 0.02	– 0.01	163	5.71*****	1.13*****	2.91*****	202	0.01	0.03	0.06
125	0.01	0.03	0.01	164	1.14*****	2.27*	5.81*****	203	– 0.01	0.02	0.04
126	0.01	0.03	0.01	165	5.71*****	1.13*	2.91*****	204	0.01	0.03	0.08
127	0.01	0.02	– 0.01	166	0.01	0.03	– 0.01	205	0.01	0.03	0.06
128	0.01	0.02	– 0.01	167	0.02	0.06	– 0.02	206	0.01	0.05	0.12
129	0.01	0.02	– 0.01	168	0.01	0.03	– 0.01	207	0.01	0.03	0.06
130	0.01	0.03	– 0.01	169	0.02	0.06	– 0.02	208	– 0.01	0.02	0.05
131	0.01	0.03	– 0.01	170	0.01	0.03	– 0.01	209	– 0.01	0.01	0.02
132	– 0.01	– 0.02	0.01	171	0.01	0.03	– 0.01	210	– 0.01	0.01	0.02
133	0.01	0.03	0.01	172	0.01	0.03	– 0.01	211	– 0.01	0.03	0.07
134	– 0.01	– 0.02	– 0.01	173	0.02	0.06	– 0.02	212	– 0.01	0.02	0.04
135	0.01	0.03	0.01	174	0.05	0.12	– 0.12	213	– 0.01	0.02	0.04
136	0.01	0.03	0.01	175	0.02	0.07	0.15	214	– 0.01	0.03	0.05
137	– 0.01	– 0.02	0.01	176	– 0.01	0.03	0.07	215	– 0.01	0.03	0.05
138	0.03	0.05	– 0.02	177	– 0.01	0.03	0.07	216	– 0.01	0.02	0.04
139	0.02	0.04	0.01	178	– 0.01	– 0.03	0.01	217	– 0.01	0.02	0.04
140	0.02	0.03	– 0.01	179	0.13	0.21	0.43	218	0.04	0.09	– 0.02
141	0.02	0.05	– 0.01	180	– 0.01	– 0.03	0.01	219	0.05	0.13	– 0.03
142	– 0.01	– 0.01	0.01	181	– 0.01	– 0.03	0.01	220	0.04	0.09	– 0.02
143	– 0.01	– 0.01	0.01	182	– 0.01	– 0.02	0.01	221	0.04	0.12	– 0.03
144	– 0.01	– 0.01	0.01	183	– 0.01	– 0.02	0.01	222	0.04	0.09	– 0.02
145	0.04	– 0.02	– 0.02	184	– 0.01	– 0.02	0.01	223	0.05	0.13	– 0.04
146	0.05	– 0.02	– 0.01	185	– 0.02	0.01	0.06	224	0.04	0.09	– 0.02
147	0.06	0.01	0.02	186	– 0.02	0.01	0.06	225	0.06	0.17	– 0.04
148	0.91	– 0.16	– 0.02	187	– 0.01	0.01	– 0.01	226	0.01	– 0.01	0.01
149	0.06	– 0.02	– 0.02	188	– 0.01	0.01	– 0.01	227	0.03	0.07	0.04
150	0.04	– 0.02	– 0.02	189	– 0.01	0.02	0.05	228	– 0.01	– 0.03	0.01
151	0.05	– 0.02	– 0.01	190	0.01	0.04	0.08	229	0.01	0.05	– 0.01
152	0.07	– 0.02	– 0.02	191	0.01	0.03	0.06	230	0.01	0.05	– 0.01
153	0.07	– 0.02	– 0.01	192	0.01	0.03	0.06	231	0.01	0.05	– 0.01

Table 3 Continuous

No	Principal components (PCs) Factor loading			No	Principal components (PCs) Factor loading		
	PC 1	PC 2	PC 3		PC 1	PC 2	PC 3
232	0.01	0.05	– 0.01	271	0.06	0.13	0.02
233	0.01	0.02	– 0.01	272	0.01	– 0.02	0.02
234	– 0.01	– 0.03	– 0.01	273	0.03	0.05	0.03
235	– 0.01	– 0.03	0.01	274	– 0.01	0.01	0.02
236	0.01	0.03	– 0.01	275	– 0.01	0.01	0.03
237	– 0.01	– 0.01	0.01	276	0.02	0.07	0.05
238	0	0	0	277	0.02	0.16	0.02
239	0.01	0.06	0.11	278	0.04	0.1	0.03
240	– 0.01	0.08	0.09	279	– 0.01	– 0.02	0.06
241	– 0.02	0.11	0.13	280	0.01	0.02	0.03
242	– 0.04	0.17	0.12	281	– 0.03	0.03	0.01
243	0.06	0.09	0.2	282	– 0.02	0.01	– 0.01
244	0.01	0.05	0.12	283	– 0.01	0.01	0.08
245	– 0.01	– 0.05	0.01	284	– 0.01	0.01	– 0.1
246	0.02	0.09	– 0.02	285	– 0.01	0.01	– 0.16
247	0.02	0.06	– 0.02	286	– 0.01	0.01	– 0.02
248	0.02	0.06	– 0.02	287	– 0.01	0.01	0.02
249	0.02	0.05	– 0.02	288	0.02	0.07	– 0.02
250	– 0.01	– 0.02	0.01	289	0.04	0.13	– 0.01
251	0.01	0.02	– 0.01	290	0.04	0.1	– 0.02
252	0.01	0.02	– 0.01	291	0.03	0.09	0.06
253	– 0.01	0.01	– 0.01	292	0.01	0.01	– 0.05
254	– 0.01	0.01	– 0.01	293	0.04	0.08	0.01
255	– 0.01	0.01	0.02	294	0.04	0.02	– 0.01
256	– 0.01	0.01	0.02	295	0.01	– 0.05	0.07
257	– 0.01	0.01	0.02	296	– 0.01	– 0.05	0.05
258	– 0.01	0.01	0.02	297	0	0	0.02
259	– 0.01	0.02	0.03	298	– 0.01	0.01	0.02
260	– 0.01	0.01	0.02	299	– 0.01	0.01	0.02
261	0.01	0.02	0.03	300	– 0.01	0.01	0.02
262	0.02	0.02	0.05	301	– 0.01	0.01	0.02
263	– 0.01	0.01	0.02	302	– 0.01	– 0.05	– 0.02
264	0.01	0.02	0.03	303	0.02	0.07	– 0.02
265	0.02	0.03	0.06	304	0.02	0.07	– 0.02
266	0.01	0.02	0.03	305	0.01	0.01	0.09
267	0.01	– 0.01	0.01	306	0.01	0.03	0.02
268	– 0.02	0.06	– 0.01	307	0.01	0.02	– 0.08
269	– 0.02	– 0.02	0.08	308	0.02	– 0.01	– 0.12
270	0.04	0.11	– 0.1	309	0.01	– 0.01	– 0.02
PCA (%)	51.9	18.45	10.02				
Percentage of total variation for the first three principal component amounts to 80.37%							

No.: number of characters, *****: highly significant characters that have high factor loading more than 1.0.

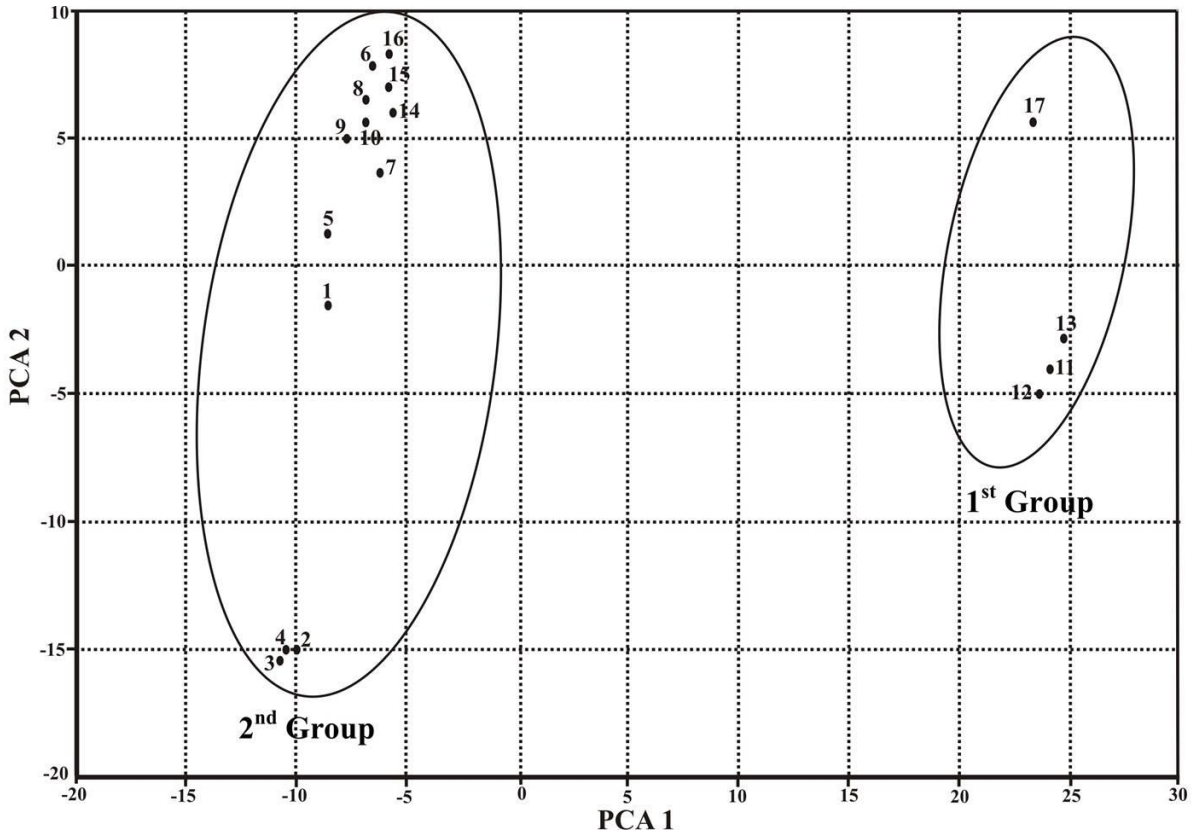

Figure 2: Scatter plot of the 17 OUTs plotted against the first principal component (PCA) by the second PCA.

Wojcik[3] recorded 28.8%, 17.4%, and 10% variations for the three principal components of 15 species of prostigmatid mites. Also, Ramadan[17] recorded 18.78%, 9.53%, and 7.90% for the first three components of 44 species of water mites. Pavan Kumar *et al*.[7] reported that three groups of 171 species were separated along the first and second ordination axis of PCA diagram. They recorded 75.9% and 19.9% variations for the first two components of mite species. In conclusion, the numerical analysis confirmed the traditional morphological taxonomy by using different analyses such as the cladistic analysis and PCA.

FUNDING SOURCE DISCLOSURE
There is no funding for this study, it jointly funded by the authors.

CONFLICT OF INTEREST
The authors declare no potential financial conflict of interest.

ACKNOWLEDGEMENTS
The authors would like to thank Prof. Dr. Tarek G. Ismail (Zoology Department, Faculty of Science, Sohag University) for his helpful advices during writing this paper.

REFERENCES

[1] Kapoor, V. C. (2001). Principles and Practices of Animal Taxonomy, 2nd Edition. Science Pub Inc, New York, NY, USA.

[2] Sokal, R. R (1963). The Principles and Practice of Numerical Taxonomy. Taxon, 12(5): 190-199.

[3] Moss, W. W and Wojcik, J. F. (1978). Numerical taxonomic studies of the mite family Harpyrhynchidae (Acari: Cheyletoidea): the higher taxa. Ann Entomol Soc Am, 71(2): 247-252.

[4] OConnor, B. M. (1984). Phylogenetic Relationships among Higher Taxa in the Acariformes, with Particular Reference to the Astigmata. In:

Acarology VI (Griffiths, D. A. and Bowman, C. E., eds), pp. 19–27. Ellis-Horwood Ltd, Chichester, Uk.

[5] Cruickshank, R. H. (2002). Molecular markers for the phylogenetics of mite and ticks. Sys Appl Acarol, 7: 3-14.

[6] Dabert, J. (2003). The feather mite family Syringobiidae Trouessart, 1896 (Acari, Astigmata, Pterolichoidae). II. Phylogeny and host-parasite evolutionary relationships. Acta Parasitol, 48: S185-S233.

[7] Pavan Kumar, S. T.; Mazumdar, D. and Karmakar, K. (2018). Numerical taxonomy of Phytoseiidae mite family: a multivariate approach. RASHI, 3(2): 57-64.

[8] Johnston, D. E. and Kethley, J. B. (1973). A numerical phenetic study of the quill mites of the family Syringophilidae (Acari). J Parasitol, 59(3): 520-530.

[9] Huang, K.-W. and Huang, T. (1990). A study on numerical taxonomy of eriophyoid mites (Acarina: Eriophyoidea). Bulletin of National Museum of Natural Science, 2: 273-279.

[10] Kuang, H. Y.; Xie, M. C. and Gong, G. J. (1992). A preliminary study on the relationship between the families of Eriophyoidea. Acta Zootaxonomica Sinica, 17: 294-298.

[11] Hong, X. and Zhang, Z.-Q. (1996). A cladistic analysis of the Eriophyoidea (Acari: Prostigmata): tests of monophyly of families. Syst Appl Acarol, 1: 107-122.

[12] Sarwar, M.; Ashfaq, M. and Akbar, S. (2005). Numerical taxonomy of two new mite species of the genus *Caloglyphus* Berlese (Acaridae) from Pakistan. Biological Sciences-PJSIR, 48(5): 345-353.

[13] Edwards, D. D. and Dimock, R. V. Jr. (1997). Genetic differentiation between *Unionicola formosa* and *U. foili* (Acari: Unionicolidae): cryptic species of molluscan symbionts. Invertebr Biol, 116(2): 124-133.

[14] Rahman, V. J.; Babu, A.; Roobakkumar, A. *et al*. (2012). Functional and numerical responses of the predatory mite, *Neoseiulus longispinosus*, to the red spider mite, *Oligonychus coffeae*, infesting tea. J Insect Sci, 12: 125 (DOI: 10.1673/031.012.12501).

[15] Simmons, T. W. and Smith, I. M. (1984). Morphology of larvae, deutonymphs, and adults of the water mite *Najadicola ingens* (Prostigmata: Parasitengona: Hygrobatoidea) with remarks on phylogenetic relationships and revision of taxonomic placement of Najadicolinae. Can Entomol, 116(5): 691-701.

[16] Proctor, H. C. (1992). Sensory exploitation and the evolution of male mating behaviour: a cladistics test using water mites (Acari: Parasitengona). Anim Behav, 44(4): 745-752.

[17] Ramadan, S. A. (2004). Numerical taxonomic studies of some aquatic mites collected from the river Nile and red sea, Egypt. Egyptian Journal of Zoology, 43: 257-275.

[18] Hussein, M. A. and Soliman, F. E. (1979a). Prostigmatic fresh water mites (Acari) in Sohag I. Tetranychoid mites. Bull Fac Sci, Assiut Univ, 8(2): 37-50.

[19] Hussein, M. A. and Soliman, F. E. (1979b). Prostigmatic fresh water mites (Acari) in Sohag II. Cheyletoid mites. Bull Fac Sci, Assiut Univ, 8(2): 51-61.

[20] Hussein, M. A. and Mazen, N. A. (1981a). Two new species of fresh water mites from the Super-family: Tetranychoidea (Acari: Actinedida: Tenuipalpidae: Tucherellidae) collected from Assiut, Egypt. Bull Fac Sci, Assiut Univ, 10: 65-72.

[21] Hussein, M. A. and Mazen, N. A. (1981b). Four new gamasid species (Acarina: Gamasida: Ascidae, Dermonyssidae: Laelaptidae) collected from fresh water bodies in Assiut,

Egypt. Bull Fac Sci, Assiut Univ, 10: 73-85.

[22] Ramadan, S. A.; Ismail, T. G. and Mustafa, A. N., (2015). A new species of parasitic water mite, *Unionicola aegyptiaca* (Acari: Unionicolidae) collected from fresh water mussel, Sohag, Egypt. Assiut Univ J of Zoology, 44(1): 1-17.

[23] Ramadan, S. A.; Ismail, T. G. and Mustafa, A. N., (2017). A new aquatic oribatid mite, *Trimalaconothrus crassipes* n. sp. (Family: Malaconothridae), Sohag, Egypt. Assiut Univ J of Zoology, 46(2): 26-39.

[24] Ramadan, S. A.; Ismail, T. G. and Mustafa, A. N., (2018). Description of two new species of aquatic oribatid mites (Family: Malaconothridae, Genus: *Malaconothrus*) from Sohag Governorate, Egypt. Egyptian Journal of Zoology, 70: 91-110.

[25] Mustafa, A. N. and Ramadan, S. A. (2022). A new species of aquatic oribatid mite "*Hydrozetes crassipes* sp. n." (Family: Hydrozetidae) from Sohag Governorate, Egypt. Egyptian Journal of Zoology, 77: 29-40.

[26] Norusis, M. J. (2000). Guide to Data Analysis: SPSS 10.0. Prentice-Hall Inc, Upper Saddle River, NJ, USA.

[27] Rohlf, F. J. (2000). NTSYS-PC: Numerical Taxonomy and Multivariate Analysis System Version 2.1. Exeter Publishing Setauket, New York, NY, USA.

[28] Smith, I. M. and Cook, D. R. (1991). Water Mites. In: Ecology and Classification of North American Freshwater Jnvertebrates (Thorp, J. H. and Covich, A. P., eds), pp. 523-592. Academic Press, San Diego, CA, USA.

[29] Avanzati, A. M.; Baratti, M. and Fabio Bernini, F. L. S. (1994). Molecular and morphological differentiation between steganacarid mites (Acari: Oribatida) from the Canary islands. Biol J Linn Soc, 52(4): 325-340.

[30] Lindquist, E. E. (1996). Phylogenetic Relationships. In: Eriophyoid Mites - Their Biology, Natural Enemies and Control (Lindquist, E. E.; Sabelis, M. W. and Bruin, J., eds), pp. 301-327. Elsevier B. V., Amsterdam, Netherlands.

How to cite this article:
Ramadan, S. A. and Mustafa, A. N. (2022). Numerical analysis of the morphological characters of some species of aquatic mites in Egypt. Egyptian Journal of Zoology, 78: 41-60 (DOI: 10.21608/ejz.2022.130389.1077).

التحليل العددى للصفات المورفولوجية لبعض أنواع الحَلَمْ المائية فى مصر

سمية أحمد رمضان، أسماء نصرالدين مصطفى

قسم علم الحيوان، كلية العلوم، جامعة سوهاج، سوهاج، جمهورية مصر العربية

الهدف من هذه الدراسة هو تحديد الوضع التصنيفي لبعض أنواع الحَلَمْ المائي واستكشاف الفرق بين التصنيف العددي والتصنيف المورفولوجي التقليدي لأنواع الحَلَمْ المائي. وبُناءً على تحليل التجميع الهرمي وتحليل المكونات الرئيسية (PCA)، تم إجراء التصنيف العددي لسبعة عشر نوعًا من الحَلَمْ المائي. وتم تطبيق هذه التحليلات على "309" صفة مورفولوجية تم جمعها من الأنواع الحالية. حيث أظهرت نتائج التحليل العنقودي المبني على مربع المسافة الإقليدية أن 17 نوعًا من الحَلَمْ المائي تم تقسيمها إلى 10 عائلات في مخطط الشجرة هى:
"Hydrozetidae, Malaconothridae, Unionicolidae, Tenuipalpidae, Tuckerellidae, Tetranychidae, Cheyletidae, Laelaptidae, Ascidae, Dermanyssidae"
وتم فصل هذه الأنواع اعتمادًا على الصفات ذات الدلالة العالية التي تحتوي على عامل تحميل أعلى من 1.0. وكانت النسب المئوية للتغيرات ذات الدلالة غير المعنوية في الصفات المورفولوجية لمجموعتين من أنواع الحَلَمْ المائي محل الدراسة كالتالي: 51.90% و 18.45% و 10.02% مع اختلاف إجمالي يساوى 80.37%. والخلاصة أنه يمكن للتحليل العددي تأكيد التصنيف المورفولوجى التقليدي باستخدام تحليلات مختلفة مثل التحليل التكويني وتحليل المكونات الرئيسية.