Research in Zoology 2014, 4(1): 20-28
DOI: 10.5923/j.zoology.20140401.04

Biosystematic Study of Sphecidae Family in Golpayegan-Isfahan Province, Iran

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Abstract The Sphecidae (Latreille, 1802) family (braided waist or digger wasps) from Hymenoptera consist of 4 subfamilies, 20 genera and about 660 species in the world. The family members are different in size (from 1.8-30 mm) wasps with distinct abdominal petiole in various color. They have important role as pollinator, plant pests, predator and parasitic in natural environments. 67 species of this family has been reported from Iran. The bees have a wide distribution almost in arid and semi arid areas of world. They have wide distribution in different habitats of Iran and almost live in pastures and arid regions. Since it is not always possible to classify animal using just morphological characters, so, in this research a new systematic approach was used by utilizing ecology, morpho-anatomy, biological interactions for more accurate taxonomy and biological fauna of the family members. In this research 6 species of this family (Ammophila heydenii Dahlbom 1845, Chalybion femoratum Fabricius 1782, Chalybion flebile Lepeletier de saint-fargeau, 1845, Sceliphron destillatorium Illiger 1807, Sphex flavipennis Fabricius 1793, Podalonia tydei Guillou 1841) reported from Golpayegan, Isfahan Province for first time. 10 Populations of 6 species of Sphecidae family were collected from different parts of Golpayegan and identified by using available references. 36 qualitative and quantitative morpho-biometrical characters were identified and studied using suitable equipments. Data were coded and analyzed by principal component analysis (PCA) test using the SPSS. Then cluster were performed. Statistical analysis of morpho-biometrical data showed that U-shaped groove in dorsal surface propodeum, Antenna color, second sub marginal cell length of front wing to basal veinlet (basal veinlet/anterior veinlet), return veins connection to sub marginal cells of front wing, teeth number in front and middle legs nails, teeth arrangement in front and middle legs nails, pulvilli between nails, foot color and angle between first abdominal tergite and petiole are more valuable tools comparing with other characters for differentiating the species.

Keywords Sphecidae, *Ammophilinae*, *Sphecinae*, *Sceliphrinae*, Iran, Isfahan Province, Golpayegan

1. Introduction

Sphecidae (mud-dauber and thread-waisted wasps or digger wasps) (Latreille 1802) is a cosmopolitan family of wasps. Traditionally, all sphecid wasps were included in a single family, Sphecidae. The traditional classification of Sphecid wasps changed with the advent of cladistics. Cladistics showed this group to be paraphiletic. Bees are closely related to sphecids now forming the family Crabronidae. Sphecidae s. str., Ampulicidae and Heterogynaidae are sister groups to bees and Crabronidae combined [1]. Both conservative definition of the Sphecidae where all the sphecid wasps are treated in a single large family and the more refined one, where the sphecid subfamilies were each elevated to family rank have recently been shown to be paraphyletic. Most specialists have considered the Sphecidae as a natural group, either as a family [2] or as a superfamily [3]. However, some specialists consider the Sphecidae to be a paraphyletic group [4], and this has been confirmed more recently by Alexander (1992) and Melo (1999) [5 & 6]. The latter specialist believes that the Sphecidae is in fact three families: *Ampulicidae*, *Sphecidae* and *Crabronidae*, which, together with the bees and the Heterogynaidae, form the superfamily Apoidea. This opinion was discussed by Brothers (1999) [7]. To refer to the three families proposed by Melo (1999) [8], the term Spheciformes has been used, a denomination already proposed by Brothers (1975 [7]. Based on some phylogenetic studies, the former family Sphecidae is now divided into four families: *Heterogynaidae*, *Ampulicidae*, *Crabronidae* and *Sphecidae* [Prentice 1998, unpublished doctoral thesis; 7 & 8]. Prentice, Brothers, and Melo independently subdivided the extant Apoidea into five monophyletic families: *Heterogynaidae*, *Ampulicidae*, *Sphecidae*, *Apidae*, and *Crabronidae* [1]. Currently there are 9660 described species in three subfamilies: *Ammophilinae*, *Sceliphrinae*, and *Sphecinae* distributed throughout the

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Published online at http://journal.sapub.org/zoology

world [9]. The family Sphecidae contains a vast array of genera and species that, collectively, are exceedingly diverse morphologically, ecologically and behaviorally [3, 10, 11]. They are worldwide in distribution, mainly occupying arid and semi arid areas, but are most numerous in warm and more or less dry habitats. While adult wasps feed on flowers, females hunt insects or spiders to provision their progeny. They are mostly specialized hunters of specific insect prey, but many species prey on a wide array of spiders. Females nest in the ground, in wood borings or plant stems, and some build exposed mud nests attached to stones or wood. A few genera consist of cleptoparasitic species. Most are active in summer months [9].

Up to now 65 species of the family have been reported from Iran by in-country authors [12, 13, 14, 15, 16, 17, 18, 19,]. Meanwhile many European and other specialists have had contributions on Iranian sphecids [20]. About 102 species in 11 genera occur in North America, including 34 species in 10 genera in Canada [21]. Also Menke (1996) studied on family Sphecidae (Sphecinae) in Costa Rica. He recorded three genera (*Ammophila* Kirby, *Eremmophila* Menke and *Podalonia* Fernald) and nine species of *Ammophilini* from Costa Rica. Then a key and illustration provided for their identification [22]. Shalan-Augul et al (2013) after collecting 409 specimens of *Ammophilini* tribe (*Hymenoptera: Sphecidae: Sphecinae*) from different region of Iraq, thirteen species belonging to four genera were determined. They recorded genus of *Parapsammophila* and six species (*Ammophila barbara*, *A. sabulosa*, *A. gracillima*, *A. hungarica*, *Podalonia minax* and *Parapsammophila turanica* as new records to the Iraqi fauna and also gave an identification keys to the subfamily, tribes, genera and species [23, 24].

Recent estimates indicate the presence of about 300 of the 9720 species occurring in the Arabian Peninsula (Ohl, own observation in Schmid-Egger 2011) [25]. The majority of the species nest in soil but certain taxa inhabit living or dead plant materiaL A few genera, such as *Sceliphron,* are muddaubers. Species of Sphecidae prey upon a tremendous variety of terrestrial insects and spiders, with host specificity ranging from absolute species-specificity to capturing several orders of insects. Some sphecids are large, showy and highly noticeable, even to a layman's eye, while others are small, obscure and rarely seen (Krombein 1979) [3].

Sphecidae use a vast of insects and arachnids to feed their larvae, although prey selection is usually limited to members of a single family or order. Prey is immobilized by the female wasps by stinging and then brought in to the nest (some species are nest parasites, i.e., they enter nests of other sphecid species and oviposit on the prey there).most species dig burrows actively in the ground for nesting or establish their nests in dead wood or in twigs, but some use preexisting cavities and other build nest out of mud because of their habits, sphecidae play an important role in their ecosystems [26].

Sphecidae is a diverse group of solitary wasps which may be of different shaped , size and color ;the female digs it nest in sand, soil or wood and provisions each nest cell with paralyzed prey and lays a single on it. The wasps larva feeds on the provisions, adults feed on nectar, pollen and juices containing high amount of sugar while the larvae need adults or larvae of different insect orders and Araneida [2, 27, 28]. The Sphecinae wasps can be recognize by many diagnostic characters such as; gaster with cylindrical elongate petiole composed of sternum only unless it has two section as in *Ammophila* Kirby, inner orbits of eyes without notch, mandibles without a notch on externo-ventral margin, notauli on scutum absent but weak and short when present, jugal lobe of hind wing large containing an anal vein, no pygidial plate, male with 13 and female with 12 antennal segments [21, 29]. They are generally black-bodied insects or black marked with white, yellow or red; some are tinged with metallic blue or green. They range in size from about 2mm up to 51 mm long [25]. In this study 36 qualitative and quantitative morpho-biometrical characters of six species of the family from Iran (Golpaygan-Isfahan Province) were identified. Then obtained data were coded and analyzed by principal component analysis (PCA) test. Then cluster were performed.

2. Materials and Methods

The adult wasps were collected by arial net, through June and July 2013 from Golpayegan region, Isfahan Province, Iran. Then all collected Sphecidae samples were prepared, mounted and then identified using available references [2, 13]. Also our identifications were confirmed by Prof. Pulawski, Gadallah, Schmid Egger and Augul. Voucher specimens were deposited at Natural History Musium of Arak University and their locality and collecting date were provided on the labels (Table 1). 26 quantitative and 15 qualitative morpho-biometrical characters were identified and studied using suitable equipments (Table 2 & 3). All of quantitative and qualitative morpho-biometerical data (Table 4) analyzed by principal component analysis (PCA) test using the SPSS (Tables 5 & 6). Then cluster were performed. Fit of the clusters to the original data was checked using cophenetic correlation (Figure 1). Finally a key based on the studied sphecideae characters was prepared (Table 7).

3. Results

Collection information of 10 collected Populations of Sphecidae family from different parts of Golpayegan-Isfahan Province, Iran have shown in Table 1. Table 4 shows quantitative morpho-biometerical characters data (M ± SD) of studied Sphecidae populations. Total variance explained for principal component analysis for studied Sphecidae population characters has been showed in Table 5. Table 6 shows six components of PCA test and correlating quantitative and qualitative morpho-biometerical characters of studied Sphecidae taxa ($P<0.05$). Analysing quantitative and qualitative morpho-biometerical characters using three

different cluster analysing method showed the Within Group method provided the best data (Figure 1). Table 7 shows an identification key based on the studied Sphecidae characters.

Table 1. Collection information of 10 collected Populations of Sphecidae family from different parts of Golpayegan-Isfahan Province, Iran

Code	Sample	Longitude	Latitude	Height(m)	Date of sampling	Place of sampling
*$CZMa_1$	*Ammophila heydenii*	50° 21′ 39″	33° 29′ 22″	1791m	2013/05/25	Golpayegan -serawar
$CZMa_2$	*Ammophila heydenii*	50° 22′ 54″	33° 28′ 56″	1791m	2013/05/24	Golpayegan -arjan
$CZMb_1$	*Chalybion femoratum*	50° 22′ 03″	33° 30′ 59″	1773m	2013/06/19	Golpayegan-Dastjerde
$CZMb_2$	*Chalybion femoratum*	50 ° 21′ 31″	33° 26′ 48″	1837m	2013/07/05	GolpayeganTivan
$CZMc_1$	*Chalybion flebile*	50° 19′ 60″	33° 34′ 00″	1755m	2013/06/18	Golpayegan-Gharghab
$CZMc_2$	*Chalybion flebile*	50 ° 22′ 03″	33° 30′ 59″	1773m	2013/05/27	Golpayegan-Dastjerde
$CZMd_1$	*Sceliphron destillatorium*	50° 21′ 39″	33° 29′ 22″	1791m	2013/05/25	Golpayegan-Serawar
$CZMd_2$	*Sceliphron destillatorium*	50° 21′ 16″	33 ° 29′ 42″	1789m	2013/06/22	Golpayegan-Sfaranjan
$CZMe_1$	*Sphex flavipennis*	50° 21′ 44 ″	33 ° 30′ 10″	1785m	2013/06/12	Golpayegan-Kalochan
$CZMf_2$	*Podalonia tydei*	50 ° 21' 39"	33° 29' 22"	1791m	2013/05/25	Golpayegan-Serawar

*CZM: Zahra Moniri collection number

Table 2. Twenty six identified quantitative morpho-biometrical characters in studied Sphecidae members from Iran (Golpaygan-Isfahan Province)

Abbreviations	Characters
Body morphology	
1. Body length (mm)	BL
Head morphology	
2. Head length max (mm)	HLM
3. Head width max (mm)	HWM
4. Head length max / Head width max (mm)	HLM/HWM
5. Antenna arthre number	AAN
6. Antenna length max (mm)	ALM
7. Antenna width max (mm)	AWM
8. Antenna length max/ Antenna width max (mm)	ALM/AWM
9. Head Color: 1 .Not black, 2. black	HC
10. Antenna color: yellow & black, 2 .black	AC
Thorax morphology	
11. Thorax length max (mm)	TLM
12. Thorax width max (mm)	TWM
13. Thorax length max / Thorax width max (mm)	TLM/TWM
14. Thorax Color: black with yellow spot, 2. Blue, 3. black	TC
15. Villi on body surface: 1. absence, 2. presence	VBS
Wing morphology	
16. Wing length max (mm)	WLM
17. Wing width max (mm)	WWM
18. Wing length max / Wing width max (mm)	WLM/WWM
19. Frontal wing sub marginal cell number	FWSMC
20. Return veins connection to sub marginal cells of front wing: 1. One vein in second & third sub marginal cell, 2. Two vein in second sub marginal cell	RVCSCFW
21. Second sub marginal cell length of front wing to basal veinlet (basal veinlet / anterior veinlet): 1. less than one, 2. equal	SSCLFW
22. Apex wing dark margin, 1. absence, 2. presence	AWDM
23. Ugal position edge of frontal wing to anal area: Surrounding all of area, 2.Surrounding more than half of area	UPEFWAA
24. Foot length max (mm)	FLM
25. Foot width max (mm)	FWM
26. Foot length max / Foot width max (mm)	FLM/FWM

Table 3. Fifteen identified qualitative morpho-biometrical characters in studied Sphecidae members from Iran (Golpaygan-Isfahan Province)

Abbreviations	Characters
1. Foot color: 1. Black & yellow, 2. Blue, 3. Black & red	FC
2. Teeth number in front & middle legs nails: 1. Simple and rarely nails with teeth, 2. Nails with 1 tooth, 3. Nails with 2 ≤ tooth	TNFLN
3. Teeth arrangement in front & middle legs nails, 1. In base of front and middle legs, 2.in edge of front and middle legs, 3. In the middle of front and middle legs	TLN
4. Pulvilli between nails, 1- absence, 2- Presence	PN
Abdomen morphology	
5. Abdomen length max (mm)	AbLM
6. Abdomen width max (mm)	AbWM
7. Abdomen length max / Abdomen width max (mm)	AbLM / AbWM
8. Angle between first abdominal tergite and petiole, 1. absence, 2. presence	AFATP
9. Respiratory pore position in first abdominal tergite: 1. More front, 2. Middle, 3. backward	RPPFAT
10. U-shaped groove in dorsal surface propodeum, 1.absence, 2.presence	USGDSP
11. Abdomen color: 1. Black, 2. Blue, 3. Black & red	AbC
12. Petiole: 1.absence, 2.presence	P
13. Petiole color: 1. yellow, 2. blue, 3. black	PC
Plant species	
14. Collection site: 1. Without plant, 2. On plant	CS
15. Plant species number: 1. Without plant, 2. One species, 2. Two species, 3. Three species	PNS

Table 5. Total variance explained for principal component analysis for studied Sphecidae populations characters

Component	Total Variance Explained					
	Initial Eigen Values			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	15.993	43.224	43.224	15.305	41.366	41.366
2	7.075	19.122	62.346	6.855	18.527	59.892
3	6.483	17.522	79.868	5.752	15.547	75.440
4	3.065	8.283	88.151	3.268	8.832	84.271
5	2.304	6.228	94.379	2.534	6.848	91.119
6	1.217	3.288	97.667	2.423	6.548	97.667
7	.592	1.601	99.268			
8	.216	.583	99.851			
9	.055	.149	100.000			
10	9.603E-16	2.595E-15	100.000			
11	8.372E-16	2.263E-15	100.000			
12	6.979E-16	1.886E-15	100.000			
13	5.030E-16	1.359E-15	100.000			
14	3.578E-16	9.670E-16	100.000			
15	3.201E-16	8.650E-16	100.000			
16	2.651E-16	7.165E-16	100.000			
17	2.242E-16	6.058E-16	100.000			
18	1.254E-16	3.390E-16	100.000			
19	8.916E-17	2.410E-16	100.000			
20	5.313E-17	1.436E-16	100.000			
21	1.629E-17	4.403E-17	100.000			
22	1.854E-18	5.012E-18	100.000			
23	5.388E-33	1.456E-32	100.000			
24	-1.667E-32	-4.505E-32	100.000			
25	-2.773E-17	-7.494E-17	100.000			
26	-4.186E-17	-1.131E-16	100.000			
27	-9.158E-17	-2.475E-16	100.000			
28	-1.307E-16	-3.533E-16	100.000			
29	-1.904E-16	-5.145E-16	100.000			
30	-2.067E-16	-5.587E-16	100.000			
31	-2.805E-16	-7.580E-16	100.000			
32	-3.022E-16	-8.167E-16	100.000			
33	-3.975E-16	-1.074E-15	100.000			
34	-4.098E-16	-1.108E-15	100.000			
35	-6.160E-16	-1.665E-15	100.000			
36	-6.730E-16	-1.819E-15	100.000			
37	-9.696E-16	-2.621E-15	100.000			

Extraction Method: Principal Component Analysis

Table 4. Quantitative morpho-biometerical characters data of studied Sphecidae populations from Golpayegan-Isfahan Province, Iran

Characters→	**BL**	**HLM**	**HWM**	**HLM/ HWM**	**ALM**	**AWM**	**ALM/ AWM**	**AAN**	**TLM**	**TWM**	**TLM/ TWM**	**WLM**	**WWM**	**WLM/ WWM**	**AbLM**	**AbWM**	**AbIm/ AbWM**	**FLM**	**FWM**	**FLM/ FWM**
Sample↓	M ± SD																			
Ammophila heydenii	21.81± 0.15	2.91± 0.15	3.23± 0.1	0.89± 0.03	4.18± 0.18	0.38± 0.01	10.81± 0.4	12.66± 0.47	5.96± 0.26	3.08± 0.12	1.93± 0.15	9.05± 0.34	2.26± 0.12	3.99± 0.13	12.94± 0.4	2.66± 0.12	4.86± 0.38	14.39± 0.29	0.85± 0.03	16.80± 0.4
Ammophila heydenii	22.12± 0.22	3.60± 0.27	3.63± 0.13	0.98± 0.09	4.05± 0.09	0.42± 0.05	9.69± 0.99	12.66± 0.47	5.28± 0.08	3.30± 0.2	1.60± 0.12	10.31± 0.57	2.63± 0.26	3.95± 0.43	13.24± 0.38	2.43± 0.28	5.51± 0.69	15.05± 0.94	0.79± 0.01	18.97± 1.22
Podalonia tydeii	19.25± 0.19	3.49± 0.11	3.94± 0.09	0.88± 0.01	5.35± 0.05	0.56± 0.03	9.55± 0.44	12.33± 0.47	6.03± 0.07	3.01± 0.03	2± 0.01	10.63± 0.05	3.16± 0.03	3.36± 0.02	9.73± 0.02	2.72± 0.02	3.57± 0.03	12.57± 0.06	0.94± 0.01	13.37± 0.17
Chalybion femoratum	16.48± 1.74	2.63± 0.47	3.08± 0.39	0.84± 0.05	5.98± 1.44	0.42± 0.02	14.25± 3.40	12.33± 0.47	6.86± 0.61	2.88± 0.27	2.38± 0.02	10.62± 0.87	2.85± 0.25	3.72± 0.05	6.99± 0.72	3.17± 0.58	2.23± 0.22	13.11± 2.38	0.86± 0.12	15.89± 5.43
Chalybion femoratum	16.02± 1.01	3.02± 0.04	3.39± 0.01	0.87± 0.01	4.66± 0.5	0.43± 0.02	10.82± 0.78	12±0	5.90± 0.56	3.04± 0.16	1.94± 0.22	10.42± 0.53	2.67± 0.03	3.89± 0.23	7.09± 0.53	3.05± 0.22	2.32± 0.18	14.92± 0.68	0.81± 0.05	18.30± 0.71
Chalybion flebile	16.96± 0.46	2.73± 0.41	3.28± 0.43	0.82± 0.05	6.59± 0.58	0.39± 0.02	17.02± 2.44	13±0	6.85± 0.32	2.50± 0.1	2.73± 0.09	10.49± 0.29	2.62± 0.18	3.97± 0.22	7.38± 0.25	2.41± 0.13	3.06± 0.08	16.10± 0.44	0.90± 0.09	18.11± 2.13
Chalybion flebile	17.95± 0.34	3.06± 0.15	3.22± 0.14	0.95± 0.03	6.87± 0.09	0.38± 0.01	18.10± 0.68	12.66± 0.47	6.56± 0.15	2.64± 0.06	2.48± 0.01	11.18± 0.03	2.97± 0.11	3.76± 0.13	8.33± 0.06	2.47± 0.1	3.37± 0.11	15.71± 0.04	0.86± 0.02	18.27± 0.47
Sceliphron destillatorium	24.37± 0.66	3.80± 0.29	4.35± 0.1	0.87± 0.04	7± 0.37	0.74± 0.04	9.46± 0.4	12±0	8.78± 0.02	5.21± 0.07	1.68± 0.02	13.95± 0.2	2.92± 0.05	4.77± 0.05	11.79± 0.36	4.09± 0.7	2.88± 0.42	17.32± 0.18	1.18± 0.1	14.67± 1.12
Sceliphron destillatorium	28.52± 0.16	4.18± 0.05	4.90± 0.02	0.84± 0.01	7.2± 0.06	0.80± 0.04	9.01± 0.36	12.33± 0.47	8.38± 0.04	3.58± 0.04	2.33± 0.02	13.96± 0.09	4.40± 0.04	3.16± 0.01	15.96± 0.08	4.37± 0.04	3.64± 0.01	20.93± 0.06	1.15± 0.04	18.21± 0.52
Sphex flavipennis	21.63± 0.45	4.40± 0.24	4.23± 0.23	1.03± 0	6.50± 0.09	0.40± 0.02	16.25± 0.63	12.33± 0.47	6.96± 0.14	4.55± 0.11	1.52± 0.01	12.2± 0.15	3.88± 0.06	3.14± 0.01	10.27± 0.09	3.98± 0.15	2.58± 0.08	15.07± 0.14	1.08± 0.06	13.95± 0.68

Table 6. Six components of PCA test and correlating quantitative and qualitative morpho-biometerical characters of studied Sphecidae taxa in Golpayegan-Isfahan Province, Iran, Bold values are positive significant ($P<0.05$)

Rotated Component Matrix[a]						
	Component					
	1	2	3	4	5	6
Thorax length max	**.958**					
Antenna color	-.950					
Collection site	-.950					
U-shaped groove in dorsal surface propodeum	**.950**					
Wing length max	**.932**					
Foot color	-.904					
Plant species number	-.894					
Foot width max	**.883**					
Antenna width max	**.877**					
Petiole color	-.850					
Thorax color	-.850					
Abdomen color	-.850					
Foot length max	**.825**					
Antenna length max	**.782**					
Abdomen width max	**.772**					
Head width max	**.758**					
Body length	.680	.652				
Abdomen length maxAbdomen width max		**.915**				
Abdomen length max		**.844**				
Apex wing dark margin		-.826				
Pulvilli between nails		-.788				
Teeth arrangement in front & middle legs nails	.522	-.778				
Teeth number in front & middle legs nails		-.695	.558			
Antenna length maxAntenna width max		-.663			.640	
REGR factor score 1 for analysis 1	.585	-.655				
Return veins connection to submarginal cells of front wing			-.941			
Second submarginal cell length of front wing to basal veinlet			-.941			
Head length maxHead width max			**.802**			
Head length max	.507		.654			
Thorax length maxThorax width max			-.645		.546	
Thorax width max	.573		.642			
Angle between first abdominal tergite and petiole				-.907		
Foot length max Foot width max				**.817**		
Respiratory pore position in first abdominal tergite		.527		.658		
Antenna arthre number					**.873**	
Wing length maxWing width max						-.931
Wing width max	.602					.698

Extraction Method: Principal Component Analysis
Rotation Method: Varimax with Kaiser Normalization
a. Rotation converged in 7 iterations.

Table 7. Sphecidae identification key based on morpho-biometerical characters of studied taxa in Golpayegan-Isfahan Province, Iran

1	a. Dorsal surface propodeum with U-shaped groove, yellow antennae first arthre and black the rest	***Sceliphron destillatorium***
	b. Dorsal surface propodeum without U-shaped groove, black antenna	**2**
2	a. Second sub marginal cell length of front wing is less than basal veinlet (basal veinlet/anterior veinlet), one return vein in second & third sub marginal cell, Nails with 2 ≤tooth	***Sphex flavipennis***
	b. Second sub marginal cell length of front wing is equal to basal veinlet (basal veinlet/anterior veinlet), two return vein in second sub marginal cell	**3**
3	a. Pulvilli presence between nails, foot black & red	***Chalybion femoratum***
	b. Pulvilli absence between nails, foot blue...	***Chalybion flebile***
	C. Pulvilli absence between nails, nails simple and rarely with teeth, teeth arrangement in front & middle legs nails is in base of front and middle legs	**4**
4	a. Presence of angle between first abdominal tergite and petiole	***Podalonia tydei***
	b. Absence of angle between first abdominal tergite and petiole	***Ammophila heydenii***

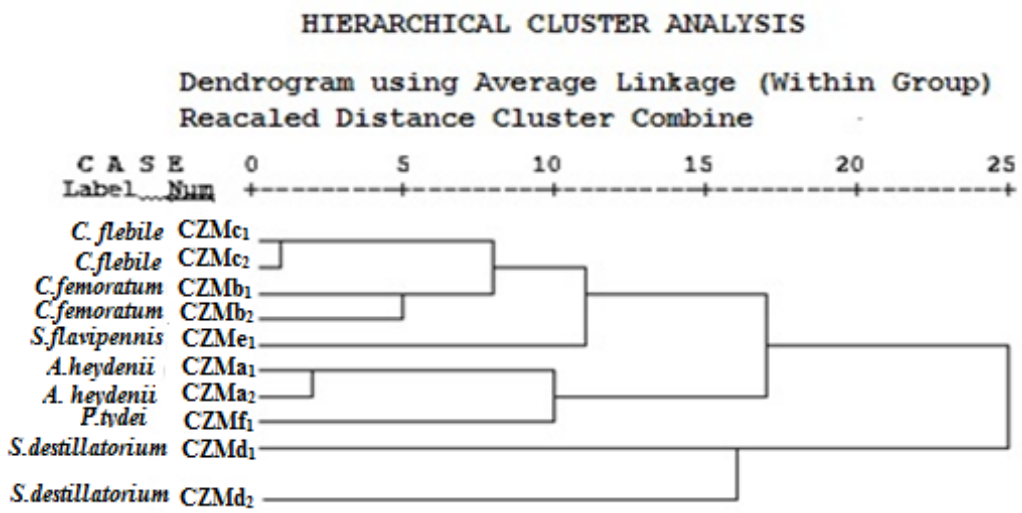

Figure 1. Cluster analysis (Within Group) of 26 quantitative and 15 qualitative morpho-biometerical characters of studied Sphecidae taxa in Gopayegan-Isfahan Province, Iran. Scored characters for cluster analysis have been shown in Tables 2 and 3

4. Discussion and Conclusions

Studies on Sphecidae morphological characters in Golpaygan -Isfahan Province, Iran showed many variations in some characters such as body length, head length and width max, head length max/head width max, antenna length and width max, antenna length max/antenna width max, antenna arthre number, thorax length and width max, thorax length max/thorax width max, wing length and width max, wing length max/wing width max, abdomen length and width max, abdomen length max/abdomen width max, foot length and width max and foot length/foot width max. Ebrahimi (1993a) and Ghazi Soltani et al (2006) used these characters for separation and identification Sphecidae genera [13, 19]. Studied qualitative characters data showed the wasps have high variation in Antenna color, Thorax Color, Return veins connection to sub marginal cells of front wing, Second sub marginal cell length of front wing to basal veinlet (basal veinle /anterior veinlet), Apex wing dark margin, Angle between first abdominal tergite and petiole, Respiratory pore position in first abdominal tergite, U-shaped groove in dorsal surface propodeum, Abdomen, Petiole and foot color, Teeth number in front & middle legs nails, Teeth arrangement in front & middle legs nails, Pulvilli between nails, collecting site and plant species number. Some researchers used these characters for Sphecidae taxa separation and identification [2, 22, 23, 24, 30].

Factor analysis results of morpho-biometerical characters in Table 5 and 6 showed that the first six factors describe about 98% of total variance. First and second components with 41% total variation were found positively correlated

with Thorax length max (TLM), U-shaped groove in dorsal surface propodeum (USGDSP), Wing length max (WLM), Foot length and width (FLM & FWM), antenna length and width max (ALM & AWM), abdomen and head width max (AbWM & HWM) and negatively correlated with antenna, foot, thorax, abdomen and petiole color (AC, FC, TC, AbC & PC), collection site (CS) and plant species number (PSN). Component 2 with 18% total variation was positive and significantly correlated with abdomen length max (AbLM) and abdomen length max/abdomen width max (AbLM/AbWM) and negatively correlated with apex wing dark margin (AWDM), pulvilli between nails (PN) and Teeth arrangement in front & middle legs nails (TLN). Component 3 with 16% total variation was correlated positively and significantly with Head length max/Head width max (HLM/HWM) and negatively correlated with return veins connection to sub marginal cells of front wing (RVCSCFW) and second sub marginal cell length of front wing to basal veinlet (basal veinlet/anterior veinlet (SSCLFW). Two last components 5 and 6 with 7% total variation were positively correlated with antenna arthre number (AAN) and negatively correlated with wing length max/wing width max (WLM/WWM) (≥ *0.7 coefficient*). In Figure 1 cluster analysis of morpho-biometerical characters data using cophenetic correlation showed two main clades: first clade consist of 2 sub-clade that first sub-clade contained 5 taxa and the second sub-clade have 3 taxa. Second clade consist of 2 populations of *Sceliphron destillatorium* species. As Figure 1 shows all of studied populations with the exception of *Sceliphron destillatorium* ($CZMd_1$ & $CZMd_2$) are in one clade that 4 populations of *Chalybion* genus ($CZMc_1$, $CZMc_2$, $CZMb_1$ and $CZMb_2$) are in 1 sub-clade. Finally study of 10 Sphecidae species using morpho-biometerical characters showed Dorsal surface propodeum with or without U-shaped groove, antenna and foot color, basal veinlet/anterior veinlet, pulvilli presence or absence between nails, nail characters and presence or absence of angle between first abdominal tergite and petiole are the most valuable and representative characters for separation of Sphecidae taxa. We know morphology was for a long time the only discipline contributing the characters for systematics and phylogenetic reconstruction [31]. Also morphometrics is used most often to seek patterns of relationship at lower levels in the taxonomic hierarchy, where mosaic patterns make intuitive pattern recognition difficult, if not possible, and in which concepts of holophyly are inappropriate [32]. Therefore study of morpho-biometerical characters are useful in distinguishing among extant genera of Sphecidae and species identification. Based on this study results an identification key was prepared (Table 7).

ACKNOWLEDGEMENTS

The authors would like to thank of Prof. Wojciech J. Pulawski, Prof. Neveen S. Gadallah and Dr. Christian Schmid-Egger for their helps in determination and confirmation of our samples.

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