

MORPHOMETRIC STUDIES ON DWARF HONEY BEE *APIS FLOREA* F. WORKERS IN SAUDI ARABIA

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Abstract

Here we performed a morphometric analysis of dwarf honey bee (*Apis florea* F.) workers from Saudi Arabia, and we detected morphometric variations within the species in the Jubail and Al-Ahsa provinces of this region. Between the two provinces, Jubail is further north and is closer to sea level, and data showed that during the collection period, Jubail experienced significantly higher humidity. Compared to workers from the Jubail province, workers from Al-Ahsa province showed significantly higher body weight, measured head appendage characteristics, wing characteristics (apart from hindwing width), leg characteristics, and length and width of the 3rd abdominal sternite and 1st wax mirror. Body weight as found to be significantly positively correlated with all determined characteristics, except for flagellum length, hindwing width, 3rd tergite length, and lengths of the 4th tergite and sternite. It can be concluded that body weight and morphometric characteristics of dwarf honey bee workers were significantly affected by geographic origin. The morphometric measurements were within the range reported from most previously examined countries.

Keywords: *Apis florea*, dwarf honey bee, morphometric, Saudi Arabia.

INTRODUCTION

Dwarf honey bees (*Apis florea* F.) are important in agriculture, medicine, and the environment (Free, 1981). They are an excellent pollinator of various economic crops and forest plants, and they have a wide foraging range (Wongsiri et al., 2000; Tahmasebi et al., 2002). The species is now well established in Sudan, where it was first detected in 1985 (Mogga and Ruttner, 1988), as well as in Iraq, Oman, and Yemen (Wongsiri et al., 1996). This bee has recently also been detected in Jordan (Haddad et al., 2008, 2009) and central Saudi Arabia (Hepburn et al., 2005), and has become widely distributed in the eastern region of Saudi Arabia. Throughout this expansion along the Arabian Peninsula and into Africa, it appears to have successfully colonized and become well adapted to the hot arid conditions of both urban and bucolical landscapes, being uninfluenced by competition from any local *Apis mellifera* (El-Shafie et al., 2002).

Morphological studies have been performed on *A. florea* from India (Bhandari, 1983; Sharma, 1983; Ruttner, 1988; Hepburn et al., 2005); Iran (Ruttner, 1988; Tahmasebi et al., 2002; Hepburn et al., 2005); Oman and Pakistan (Ruttner, 1988; Hepburn et al., 2005); Sri-Lanka (Ruttner, 1988; Hepburn et al., 2005); Thailand (Ruttner, 1988; Rinderer et al., 1995; Chaiyawong, 2001; Chaiyawong et al., 2004; Hepburn et al., 2005); Cambodia, Myanmar, Nepal, and Vietnam (Hepburn et al., 2005); and Jordan (Haddad et al., 2009). These investigations have revealed inter-locality variations in most of the morphometric characteristics measured in *A. florea* workers. Tahmasebi et al. (2002) studied the effects of geographical and climatic conditions on the morphological variations among Iranian small honey bees (*A. florea* F.), and found two distinct populations: a class of larger bees residing in the southwest of Iran, and a class of smaller bees residing in the southeast of Iran. Similarly, Bhandari (1983) and Sharma (1983) each reported significant inter-locality differences in the mean values of morphometric characteristics and

in the coefficients of variation for most characteristics measured in *A. florea* F. in India.

The present study aimed to investigate the morphometric characteristics of dwarf honey bee *A. florea* F. workers under the environmental conditions present in Saudi Arabia. Our second goal was to detect the variation within this species between two provinces in this region.

MATERIAL AND METHODS

These investigations were conducted at the laboratory of the Department of Arid Land Agriculture, College of Agriculture and Food Sciences, King Faisal University, Al-Ahsa, Kingdom of Saudi Arabia. During the sidir (*Ziziphus* spp.) season from mid-September to mid-November of 2011, 80 *Apis florea* colonies were selected from the Al-Ahsa and Jubail provinces (forty colonies from each). Al-Ahsa lies at latitude 25° 25' 46" N and longitude 49° 37' 19" E and an altitude of 121 m above sea level, while Jubail is at latitude 27° 0' 16.0" N, longitude 49° 39' 41.0" E, and an altitude of 12 m above sea level.

From the selected colonies, parts of combs containing ripe worker sealed broods were cut and inserted into wooden cages (15.5 × 12 × 12 cm) with three sides of metal net. These cages were then placed into an incubator at 31°C and relative humidity (R.H.) of 45 until workers emerged. Within 3 h of emergence, 50 newly emerged workers were collected from each cage. The workers were chilled, and then their fresh body weights (in mg) were determined using an electronic scale. They were then preserved in 70% ethanol until dissection.

The eighteen morphological characteristics examined in this study were proboscis length, flagellum length, total antenna length, length and width of right forewing and hindwing, number of hamuli on the right hindwing, femur length, tibia length, and width of the end of tibia, length of the 3rd and 4th abdominal tergite and sternite, and length and width of the 1st wax mirror. The examined body parts were removed and placed on glass slides to measure the lengths and widths (in mm) using a dissecting binocular microscope equipped with a micrometer lens.

During the experimental period, meteorological data (air temperature, relative humidity, wind velocity, rainfall, and soil temperature at 5 cm) were obtained from the Meteorological Station of Agricultural and Veterinary Training and Research Station, King Faisal University, Al-Ahsa, as well as from Royal Commission for Jubail, Kingdom of Saudi Arabia. Data were recorded using Campbell Scientific CR 3000.

Data were statistically analyzed by ANOVA. Pearson correlation between characteristics was determined using SAS Institute (2003).

RESULTS

The obtained data showed that body weight and 14 of the 18 examined morphometric characteristics of dwarf honey bee (*Apis florea*) workers were significantly affected by geographic location (Tab. 1). Compared to those from Jubail province, workers from Al-Ahsa province exhibited significantly higher values ($p < 0.01$) for body weight, proboscis length, flagellum length, total length of antenna, forewing length and width, hindwing length, number of hamuli, tibia length and width, and 1st wax mirror width. The values for femur length, metatarsus length, 3rd sternite length, and 1st wax mirror length were also significantly higher (at the significance level of $p < 0.05$) than those of workers from Jubail province. Four morphometric characteristics (hindwing width, 3rd tergite length, and lengths of the 4th tergite and sternite) were not significantly affected by colony location.

Body weight was significantly positively correlated with all determined characteristics, except for flagellum length, hindwing width, 3rd tergite length, and lengths of the 4th tergite and sternite. Forewing length was also found to be significantly positively correlated with proboscis length, antenna length, forewing width, hindwing length, tibia length and width, 3rd sternite length, and 1st wax mirror length and width. Third sternite length was also found to be significantly positively correlated with all determined characteristics, except for proboscis length, hindwing width, 4th sternite length, and 1st wax mirror length and width. We also found that 1st wax mirror width was significantly positively correlated with proboscis length, antenna length, forewing length and width, hindwing width, number of hamuli, determined leg characteristics, and 1st wax mirror length (Tab. 2).

The relative humidity values obtained for Jubail province were significantly ($p < 0.05$) higher than those of Al-Ahsa province. During the experimental period, air temperature, wind velocity, rainfall, and soil temperature did not significantly differ between the two locations (Tab. 3).

Table 1.

Mean body weights and average measurements of 18 morphometric characteristics of dwarf honey bee (*Apis florea*) workers collected from the Al-Ahsa and Jubail provinces

Character		Mean \pm standard deviation (Range)		CV
		Al-Ahsa	Jubail	
Body weight (mg)		31.01 \pm 0.53 (30.16 - 31.88)	30.20 \pm 0.29** (29.64 - 30.64)	1.73
Proboscis length (mm)		3.22 \pm 0.06 (3.10 - 3.30)	3.14 \pm 0.08** (3.00 - 3.20)	2.70
Flagellum length (mm)		1.73 \pm 0.03 (1.67 - 1.75)	1.69 \pm 0.06** (1.65 - 1.75)	2.34
Total antenna length (mm)		2.75 \pm 0.05 (2.71 - 2.82)	2.70 \pm 0.04** (2.69 - 2.74)	1.62
Forewing	Length (mm)	6.27 \pm 0.05 (6.20 - 6.30)	6.20 \pm 0.05** (6.10 - 6.30)	1.09
	Width (mm)	2.36 \pm 0.04 (2.30-2.40)	2.24 \pm 0.07** (2.10-2.30)	2.32
Hindwing	Length (mm)	4.40 \pm 0.08 (4.30 - 4.50)	4.23 \pm 0.15** (4.00 - 4.40)	2.61
	Width (mm)	1.51 \pm 0.07 (1.40 - 1.60)	1.47 \pm 0.07 (1.40 - 1.60)	4.99
	No. hamuli	12.40 \pm 0.51 (12.00 - 13.00)	11.70 \pm 0.48** (11.00 - 12.00)	6.06
Femur length (mm)		1.73 \pm 0.04 (1.65 - 1.75)	1.67 \pm 0.06* (1.63 - 1.70)	3.03
Tibia length (mm)		2.14 \pm 0.08 (2.05 - 2.30)	2.07 \pm 0.35** (1.95 - 2.10)	10.70
Tibia width (mm)		0.72 \pm 0.03 (0.70 - 0.80)	0.69 \pm 0.03** (0.67 - 0.70)	5.06
Metatarsus length (mm)		1.39 \pm 0.02 (1.35 - 1.43)	1.36 \pm 0.04* (1.33 - 1.40)	2.57
3 rd tergite length (mm)		1.41 \pm 0.03 (1.38 - 1.45)	1.38 \pm 0.05 (1.33 - 1.43)	2.52
3 rd sternite length (mm)		1.70 \pm 0.06 (1.65 - 1.75)	1.65 \pm 0.08* (1.63 - 1.70)	4.34
4 th tergite length (mm)		1.35 \pm 0.06 (1.30 - 1.45)	1.33 \pm 0.05 (1.30 - 1.45)	4.14
4 th sternite length (mm)		1.54 \pm 0.05 (1.50 - 1.56)	1.52 \pm 0.02 (1.50 - 1.55)	2.80
1 st Wax mirror	Length (mm)	0.82 \pm 0.02 (0.79 - 0.85)	0.80 \pm 0.02* (0.77 - 0.80)	4.86
	Width (mm)	1.35 \pm 0.05 (1.30 - 1.40)	1.26 \pm 0.05** (1.20 - 1.30)	3.30

**p<0.01 between provinces, *p<0.05 between provinces.

Table 2.
Pearson correlation coefficients for body weight and 18 characteristics of dwarf honey bee (*Apis florea*) workers

Character-istics	Body weight	Proboscis length	Antenna length	Forewing length	Forewing width	Hindwing length	Hindwing width	No. hamuli	Femur length	Tibia length	Tibia width	Meta-tarsus length	3 rd tergite length	3 rd sternite length	4 th tergite length	4 th sternite length	1 st Wax mirror length	1 st Wax mirror width
Body weight																		
Proboscis length	0.69**																	
Flagellum length	0.21	0.21																
Antenna length	0.48*	0.34	0.69**															
Forewing length	0.72**	0.61**	0.30	0.44*														
Forewing width	0.74**	0.52**	0.46*	0.58**	0.76**													
Hindwing length	0.53**	0.37	0.33	0.42	0.61**	0.62**												
Hindwing width	0.36	0.39	0.14	0.21	0.20	0.32												
No. hamuli	0.54**	0.43*	0.70**	0.39	0.34	0.47*	0.38											
Femur length	0.45*	0.37	0.27	0.40	0.20	0.45*	0.48*	0.14										
Tibia length	0.63**	0.41	0.35	0.24	0.47*	0.27	0.52**	0.44*	0.31	0.39								
Tibia width	0.56**	0.32	0.40	0.35	0.45*	0.60**	0.46*	0.33	0.34	0.66**	0.64**							
Metatarsus length	0.43*	0.49*	0.46*	0.37	0.38	0.64**	0.56**	0.27	0.30	0.56**	0.46*	0.32						
3 rd tergite length	0.31	0.15	0.49*	0.45*	0.09	0.32	0.27	-0.07	0.43*	0.56**	0.28	0.54**	0.37					
3 rd sternite width	0.63**	0.33	0.50**	0.70**	0.48*	0.65**	0.51*	0.06	0.47*	0.55**	0.27	0.54**	0.54**	0.70**				
4 th tergite length	0.33	0.08	0.55**	0.31	0.16	0.24	-0.13	0.09	0.47*	0.01	0.21	0.39	0.39	0.47*	0.57**			
4 th sternite width	0.25	0.14	0.30	0.33	0.25	0.38	0.44*	0.30	0.40	0.38	0.50*	0.57**	0.57**	0.37	0.26	0.14		
1 st Wax mirror length	0.57**	0.48*	0.11	0.21	0.46*	0.57**	0.54**	0.36	0.42	0.39	0.59**	0.33	0.33	0.11	0.20	-0.14	0.60**	
1 st Wax mirror width	0.56**	0.55**	0.31	0.42	0.44*	0.64**	0.49*	0.35	0.26	0.47*	0.65**	0.47*	0.47*	0.24	0.38	0.09	0.32	0.44*

*Correlation is significant at the 0.05 level (2-tailed). **Correlation is significant at the 0.01 level (2-tailed).

Table 3.

The mean values of meteorological factors
in the Al-Ahsa (A) and Jubail (J) provinces of Saudi Arabia from September to November of 2011

Month	Air temperature (°C)		Relative humidity (%)		Wind velocity (m/sec)		Rainfall (mm)		Soil temperature (°C)	
	A	J	A	J	A	J	A	J	A	J
Sep.	33.39	32.90	27.42	46.20*	2.17	2.35	0.00	0.00	35.27	34.63
Oct.	27.81	28.05	37.48	51.19*	2.06	2.81	0.00	0.00	32.39	32.40
Nov.	20.13	20.75	48.67	57.04*	2.66	3.30	0.03	0.06	27.56	28.65

*Significant difference between provinces at the 5% level according to Duncan's Multiple Range Test.

DISCUSSION

The mean body weights of the *A. florea* workers were 30.20 and 31.01 mg for the Jubail and Al-Ahsa provinces, respectively. This inter-locality difference was significant ($p < 0.01$), and could be related to environmental variations, especially relative humidity, which significantly differed between the two locations. Several groups have previously reported decreased daily activity of honey bees on days characterized by maximum relative humidity (Patil and Viraktamath, 2001; Kumar et al., 2002; Mordago et al., 2002). This activity decrease might affect food collection, and thus body size. Our results also confirmed the findings of Tahmasebi et al. (2002), who reported that more northern areas with higher altitudes and more precipitation have larger honeybees. In India, the weight of the *A. florea* worker ranges from 17.00 to 31.00 mg, with an average of 25.00 mg (Kshirsagar et al., 1983). In northern Thailand, the average adult worker weighs 29.20 mg in the winter and 31.20 mg in the summer season (Burgett and Titayavan, 2004).

Among the measured head characteristics of the *A. florea* worker, the mean lengths of the proboscis, flagellum, and antenna were significantly affected ($p < 0.01$) by colony location. These differences could be correlated to body weight, as body weight was significantly positively correlated with proboscis length ($r = 0.69$; $p < 0.01$) and antenna length ($r = 0.48$; $p < 0.05$) (Tab. 2). The overall average proboscis, flagellum, and antenna lengths for *A. florea* workers from Saudi Arabia were 3.18, 1.71, and 2.73 mm, respectively, which were lower than those measured from *A. florea* from Thailand: 3.33, 1.77 and 2.82 mm, respectively (Chaiyawong et al., 2004) (Tab. 4).

Significant inter-locality variations were observed in the measured values for forewing length and width, hindwing length and width, and number of hamuli ($p < 0.01$). Inter-locality variations in wing character-

istics have also been reported by Bhandari (1983), Sharma (1983), and Tahmasebi et al. (2002). The differences in measured wings characteristics could result from the significant ($p < 0.01$) variation in body size. Body weight was found to significantly ($p < 0.01$) positively correlate with forewing length ($r = 0.72$) and width ($r = 0.74$), hindwing length ($r = 0.53$), and number of hamuli ($r = 0.54$). The mean values were 6.24 mm for forewing length, 2.30 mm for forewing width, 4.32 mm for hindwing length, 1.49 mm for hindwing width, and 12.05 hamuli, which were each higher than the values reported for workers from Thailand—except for forewing length, which was lower (Rinderer et al., 1995). Chaiyawong et al. (2004) reported the same trend for forewing length and hamuli number. Forewing length in the present study (6.24 mm) was lower than those reported from Cambodia (6.58 mm), Sri-Lanka (6.85 mm), Myanmar (6.44 mm), Nepal (6.33 mm), Oman (6.52 mm) and Pakistan (6.61 mm), while it was higher than those reported from India (6.13 mm), Iran (6.14 mm), Thailand (6.17 mm), and Vietnam (6.23 mm) (Hepburn et al., 2005).

We also observed significantly ($p < 0.05$) different measured leg characteristics between workers from the two locations in Saudi Arabia. Body weight was found to be significantly positively correlated with femur length ($r = 0.45$; $p < 0.05$), tibia length ($r = 0.63$; $p < 0.01$), and tibia width ($r = 0.56$; $p < 0.01$) (Tab. 2). The overall average values for the whole population were 1.70 mm for femur length, 2.11 mm for tibia length, 0.71 mm for tibia width, and 1.38 mm for metatarsus length, which were higher than the values obtained from south India (femur length, 1.67 mm; tibia length, 2.09; and metatarsus length, 1.29), but lower than those from Iran (femur length, 1.83 mm; tibia length, 2.30; and metatarsus length, 1.41 mm) (Tab. 4). In Thailand, the same trend was observed for femur and tibia lengths, while the opposite trend was observed for metatarsus length (Rinderer et al., 1995; Chaiyawong et al., 2004).

Table 4.

Morphometric comparison of dwarf honey bee workers in Saudi Arabia and other countries

Character	Saudi Arabia	1	Thailand	2	3	Cambodia ³	India ³	Sri-Lanka ³	Iran	Myanmar ³	Nepal ³	Oman ³	Pakistan ³	Vietnam ³
Body weight (mg)	30.61	-	-	-	-	-	-	-	-	-	-	-	-	-
Proboscis length (mm)	3.18	3.33	3.27	-	-	-	-	-	-	-	-	-	-	-
Flagellum length (mm)	1.71	1.77	-	-	-	-	-	-	-	-	-	-	-	-
Total length of antenna (mm)	2.73	2.82	-	-	-	-	-	-	-	-	-	-	-	-
Forewing														
Length (mm)	6.24	6.29	6.45	6.17	6.13	6.58	6.14	6.85	6.76	6.44	6.33	6.52	6.61	6.23
Width (mm)	2.30	-	2.25	-	-	-	-	-	2.36	-	-	-	-	-
Length (mm)	4.32	-	3.17	-	-	-	-	-	4.71	-	-	-	-	-
Hindwing														
Width (mm)	1.49	-	1.36	-	-	-	-	-	1.49	-	-	-	-	-
No. hamuli	12.05	11.17	11.10	-	-	-	-	-	11.86	-	-	-	-	-
Femur length (mm)	1.70	1.72	1.76	1.74	1.72	1.74	1.67	1.83	1.83	1.76	1.74	1.74	1.75	1.78
Tibia length (mm)	2.11	2.18	2.22	2.22	2.24	2.19	2.09	2.30	2.29	2.27	2.29	2.17	2.18	2.29
Tibia width (mm)	0.71	-	-	-	-	-	-	-	-	-	-	-	-	-
Metatarsus length (mm)	1.38	1.25	1.34	1.35	1.38	1.35	1.29	1.41	1.41	1.39	1.39	1.35	1.35	1.37
3 rd tergite length (mm)	1.40	1.37	1.41	1.41	1.45	1.40	1.32	1.51	-	1.44	1.47	1.39	1.40	1.43
3 rd sternite width (mm)	1.68	-	-	-	-	-	-	-	-	-	-	-	-	-
4 th tergite length (mm)	1.34	1.33	1.36	1.36	1.40	1.37	1.27	1.47	-	1.38	1.40	1.34	1.37	1.37
4 th sternite width (mm)	1.53	-	-	-	-	-	-	-	-	-	-	-	-	-
1 st Wax mirror														
length (mm)	0.81	0.76	0.78	-	-	-	-	-	-	-	-	-	-	-
width (mm)	1.31	-	1.42	-	-	-	-	-	-	-	-	-	-	-

1 - Chaiyawong et al. (2004); 2 - Rinderer et al. (1995); 3 - Hepburn et al. (2005); 4 - Özkan et al. (2009)

The mean values for length and width of the 3rd sternite and 1st wax mirror significantly differed between workers from Al-Ahsa and Jubail. These differences were related to variations in worker body size. Body weight was significantly ($p < 0.01$) positively correlated with 3rd sternite length ($r = 0.63$) and 1st wax mirror length ($r = 0.57$) and width ($r = 0.56$). The mean lengths of the 3rd and 4th tergite were 1.40 and 1.34 mm, respectively. The same values were recorded for 3rd tergite in India and Pakistan, and 4th tergite in Oman (Hepburn et al., 2005). The present values were higher than those reported from Thailand (Chaiyawong et al., 2004) and Sri-Lanka (Hepburn et al., 2005), but lower than those reported from other studies in Thailand (Rinderer et al., 1995; Hepburn et al., 2005), as well as from Cambodia, Iran, Myanmar, Nepal, and Vietnam (Hepburn et al., 2005). Regarding the 1st wax mirror for bees from Saudi Arabia in the present study, the mean length was longer than those from Thailand (Rinderer et al., 1995; Chaiyawong et al., 2004), while the mean width was shorter than those from Thailand (Rinderer et al., 1995).

CONCLUSION

It can be concluded that body size and most morphometric characteristics of dwarf honey bee (*A. florea*) workers significantly varied according to geographical origin. Additionally, most measured values of characteristics of dwarf bees in Saudi Arabia were lower than those previously reported from Pakistan, Nepal, Myanmar, Thailand, India, and Iran, while they were higher than those reported from Sri Lanka.

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