Body morphological characteristics of honey bees

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ABSTRACT
Honey bees (Apis mellifera) consist of more than 24 different subspecies. Most of these subspecies have been classified according to their morphological characteristics, and morphological characteristics thus have an important role in the classification aspects of honey bees. Different sets of wing and body morphological characteristics have been used to characterize and classify the subspecies by many authors and for various reasons. These characteristics were defined over time and combined from various studies. Wing venation characteristics have been studied more intensely than other body morphological characteristics. Up to now there are no specific review articles focus mainly on body morphological characteristics. Therefore, the available information about sampling method, measuring method, importance and factors affecting these characteristics were reviewed to present essential conclusion and recommendations for researchers.

Key words: Apis mellifera, morphometry, body characteristics, honey bees

INTRODUCTION
The honey bee, Apis mellifera L., is globally widespread with a wide diversity of subspecies. These subspecies can be classified with morphometric tools (Ruttner et al. 1978). Many studies have been undertaken on honey bees using morphological characteristics (e.g. Abou-Shaara et al. 2012 and Garnery et al. 2004). These characteristics can be divided into three major groups; which are length measurements, color measurements, and wing venation characteristics. Wing venation characteristics were previously reviewed intensively by Abou-Shaara (2013). Here, the major studies that have been done using body morphological characteristics were reviewed to provide recommendations about sampling, measuring method and limitations of body morphological characteristics.

IMPORTANCE OF MORPHOLOGICAL MEASUREMENTS

Body morphological characteristics can be measured for different reasons. A major use is to characterize honey bee races and individuals (Ruttner 1988, Meixner et al. 2007), but also to determine the degree of hybridization with foreign races (Radloff et al. 2003 and Bienefeld et al. 1996). Also, for the discrimination between honey bee subspecies (e.g. Abou-Shaara and Al-Ghamdi 2012, Toﬁliski 2004). Moreover, morphological characteristics were measured to investigate the impacts of imported queens on honey bee populations (Guler 2010) or to check populations purity (Miladenovic et al. 2011). Multiple body characteristics, including wing length, wing width and tongue length were used to differentiate between honey bee subspecies (Buco et al. 1987, Rinderer et al. 1993, Crewe et al. 1994, Ftayeh et al. 1994, Diniz-Filho and Malaspina 1995, Szymula et al. 2010).

Tongue length was found to be an indicator of geographical variation in some studies (Marghitas et al. 2008, Morimoto 1968, Souza et al. 2002). Proboscis length was also found to be the most differentiated characteristics between A.m.mellifera, A.m.carnica and A.m.caucasica (Szymula et al. 2010). In addition, body measurements may show correlations to honey yield. Kolmes and Sam (1991) found that honey production was highly correlated to overall size, corbicular area and wing measurements in Carniolan honey bees. Body characteristics may thus be used for indirect prediction of colony productivity or for selection of productivity where honey bees with bigger legs and wings have higher power flight and could gather more pollen and nectar for brood rearing and consequently colony population (Mostajeran et al. 2006). There is a positive correlation between honey production and corbicular area (Milne and Pries 1984). Szabo and Lekovich (1988) found that honey production had significant and positive correlations with both fore and hind wing area. Mostajeran et al. (2002) found that honey production was related to tongue length, fore wing length and width, hind wing length, leg length, femur length, tibia
length and metatarsus width. Waddington (1989) found a correlation between body size and colony productivity. Edriss et al. (2002) indicated that honey production can be improved through selection of the forewing width. Therefore, there is evidence that body morphological characteristics are very important and correlated with colony productive characteristics. However, it must be noted that these relations may attribute to specific conditions rather than indicating general rules.

COLLECTION OF BEE SAMPLES

At least 15 honey bee workers should be collected from each colony during the morphological analysis (Ruttner et al. 2000, Sheppard and Meixner 2003, Meixner et al. 2007, Guler 2010) and at least eight colonies per district can be considered sufficient for morphological study (Abou-Shaara et al. 2012). However, Miguel et al. (2011) used only one honey bee worker per colony for geometric morphometric but generally more is required to obtain reliable results. Samples can be collected in a number of ways (i) directly from brood comb according to Padilla et al. (1992). (ii) shaking bees into a jar, (iii) collecting forager bees (iv) taking one-day old bees by placing sealed brood combs into incubators. Collected bees can be preserved in 95% ethanol until dissection (Arias et al. 2006) or in 70% ethanol (Adl et al. 2007) or killing by a deep-freezer and then dissected (Abou-Shaara et al. 2012). Also, the temporary preparation of the samples can be used (Miladenovic et al. 2011).

It needs to be taken into account that there are some factors that can impact on the morphological characteristics. Comb cell size has an impact on morphological characteristics (Ruttner 1988, McMullan and Brown 2006, Gencer and Firati 2005) where workers emerged from large wax cells have larger morphological characteristics. Sample size and time of taking the samples thus could affect comparisons between different data for body morphological characteristics. In general, it is very important to take samples for morphological analysis at the same time for all studied replicates and try taking samples from new combs and under the same condition of feeding as possible.

METHODS OF MEASURING BODY MORPHOLOGICAL CHARACTERISTICS

After the collection of the samples, samples can be mounted on sticky pieces as described by Abou-Shaara and Al-Ghamdi (2013) to facility characteristics measuring. Also, other mounting methods for body parts (e.g. double glass slides) can be used (Abou-Shaara et al. 2011). Several methods have been used to take the body measurements; (i) stereomicroscope with an ocular micrometer (Ruttner et al. 1978, Mattu and Vermam 1984, Edriss et al. 2002, Souza et al. 2002, Sirali et al. 2003, Gencer and Firati 2005, Cakmak et al. 2006, Tan et al. 2006, Mostajeran et al. 2006, Adl et al. 2007, Marghitas et al. 2008). (ii) Photomicroscope (Morris-Olson 2002). (iii) Projecting mounted slides onto a TV screen

BODY CHARACTERISTICS

Various body characteristics of honey bees were measured by many authors (e.g. Meixner et al. 2007, Shaibi et al. 2009, Miladenovic et al. 2011, Abou-Shaara et al. 2012, Abou-Shaara...
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and Al-Ghamdi 2012). Commonly, body characteristics are normally measured according to Ruttner et al. (1978) and Ruttner (1988). These characteristics can be divided according to body parts into; head, thorax and abdomen characteristics. (i) head characteristics include; head capsule width (HCW) and length (HCL), antenna length (AL) and number of segments (ANS), compound eye length (CEL) and width (CEW), and tongue length (TonL). Some authors also studied the mandible length (ML) beside some other characteristics. (ii) thorax characteristics; fore wing length (FWL) and width (FWW), hind wing length (HWL) and width (HWW), number of hooks (NH), thorax width (ThW), femur length (FL), tibia length (TL), basetarsus length (BL) and width (BW), and pollen basket size (PBS), brush hair rows number (HN). (iii) abdomen characteristics; lengths of tergit 3 (T3) and 4 (T4), body size (T3+T4), length of hairs on tergit 5 (HLT5), pigmentation of tergit 2-4, length of sternite 3 (LS3), wax mirror length (WML) and transversal (WMT) and sting shaft length (StL). In general, measurements have to be taken as the maximum distance and in units of millimeters (mm) except the number of hooks. Moreover, there are some indexes were revealed from these characteristics (e.g. forewing index = length /width of fore wing).

FACTORS AFFECTING BODY MEASUREMENT VARIATION

Previous works on honey bee workers showed that environmental factors have a major impact on morphological characteristics (Eischen et al. 1982, Milne and Pries 1984, Milne et al. 1986, Stanimirovic et al. 2008). Marghitas et al. (2008) found that in the mountain regions of Transylvania for example worker proboscises were longer 6.21 mm than that in lower regions 5.99 mm. The importation of honey bee subspecies into different areas might induce high levels of hybridization within populations (Garnery et al. 1998, Rortais et al. 2004, Alqarni et al. 2011) and produce subspecies admixtures (Arias et al. 2006). Also, migratory beekeeping may play a key role in forming differences (Marghitas et al. 2008). Morphological characteristics for uncontrolled honey bee populations showed low stability through time (Abou-Shaara et al. 2012). Thus to characterize uncontrolled populations, taking the characteristics mean for two successive years is highly recommended. Some other factors that may impact on wing and body morphological characteristics were reviewed by Abou-Shaara (2013).

CONCLUSIONS

Various methods were used in taking morphological measurements. However, computer-based methods using programs (e.g., Photoshop, image tool and AutoCAD) could be recommended to save time and obtain accurate measurements. It is worth noting that the sample size, sampling season, sampling technique and measuring method differ from author to another and from country to another and should be better harmonized. Therefore, it is recommended to use standard methods for measuring these characteristics to facilitate comparing results of different subspecies and countries. Figure 1 shows the recommended steps for the morphometric analysis based on body characteristics. Fifteen workers per colony and six colonies per district should be sufficient for sample size. Taking samples from colony combs are easier than forager bees. Ongoing evaluation of morphological characteristics could help in understanding racial fluctuations due to beekeeping, hybridization and environmental factors. In addition, morphological characteristics are also correlated with colony productive characteristics. As a result, body morphological characteristics can be used as a simple indicator for estimating fluctuations in genetic and productive characteristics of honey bee colonies. It is apparent that still more work is required to provide insights into the seasonal impacts on body morphological characteristics.

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REFERENCES

8. Andere C, Garcia C, Marinelli C, Cepeda R, Rodriguez EM, Palacio A. Morphometric variables of honeybees Apis mellifera used in ecotypes characterization in Ar-
9. Arias MC, Rinderer TE, Sheppard WS. Further characteri-
   zation of honey bees from the Iberian peninsula by al-
   lozyme, morphometric and mtDNA haplotype analy-
    D, Ruttner F. Report on present situation of Apis mellif-
11. Buco SM, Rinderer TE, Sylvester HA, Collins AM, Lan-
    caster VA and Crewe RM. Morphometric differences
    between South American Africanized and South Afri-
    can (Apis mellifera scutellata) honey bees. Apidologie
    1987;18:217-222
12. Cakmak I, Fuchs S, Nentchev P, Meixner M. Morpho-
    metric analysis of Honeybees in northern Turkey. Sec-
    ond European Conference of Apidology, Prague 10th
13. Crewe RM, Hepburn HR, Moritz RFA. Morphometric
    analysis of 2 southern African races of honey bee. Api-
    dologie 1994;25:61-70
14. Diniz-Filho JAF, Malaspina O. Evolution and population
    structure of Africanized honey bees in Brazil: Evidence
    from Spital analysis of morphometric data. Evolution
    1995;49:1172-1179
15. Edriss MA , Mostajeran M, Ebadi R. Correlation be-
    tween honey yield and morphological traits of honey
    91-103.
16. Eischen EA, Rothenbuhler WC, Kulincevic JM. Length
    of life and dry weight of worker honeybees reared in
17. Ftayeh A, Meixner M, Fuchs S. Morphometrical inves-
    tigation in Syrian honey bees. Apidologie 1994;25:396
    –401.
18. Garnery L, Sheppard WS, Baylac M, Arnold G. Genetic
    diversity of European honeybees. First European Con-
    ference of Apidology, Udine 19-23 September, 2004;
    35pp.
19. Garnery L, Franck P, Baudry E,Vautrin D, Comuet JM,
    Solignac M. Genetic diversity of the west European
    honey bee (Apis mellifera mellifera) and (Apis mellifera
    31–47.
20. Gencer HV, Firati C. Reproductive and morphological
    comparisons of drones Reared in queenright and laying
21. Gulser A. A morphometric model for determining the
    effect of commercial queen bee usage on the native hon-
    eybee (Apis mellifera L.) population in a Turkish prov-
    ince. Apidologie 2010;41:622–635.
22. Haddad N, Fuchs S. Honeybee agrobiodiversity: a proj-
    ect in conservation of Apis mellifera syriaca in Jordan.
    BP. The effects of rearing temperature on developmental
    ability and learning and memory in the honey bee , Apis
24. Kamel SM, Strange JP, Sheppard WS. A Scientific note on
    hygienic behavior in Apis mellifera lamarckii and A.
    m. carnica in Egypt. Apidologie 2003; 34: 189 -190.
25. Kandemir I, Kence M, Kence A. Genetic and Morpho-
    metric variation in honeybee (Apis mellifera) popula-
26. Kolmes SA, Sam Y. Relationships between sizes of mor-
    phological features in worker honeybees (Apis mellif-
27. Marghitas AL, Panitì-Teleky O, Dezmiran D, Margoaon
    R, Bojan C, Coroian C, Laslo L, Moise A. Morphometric
    differences between honey bees (Apis mellifera carpat-
    ica) Populations from Transylvanian area, Zootehnie Si
28. Mattu VK, Verma LR. Morphometric studies on the In-
    dian honeybee, Apis cerana indica F. Effects of seasonal
29. May-Itza WJ, Quezada Euán JJG, Iui L, Echazarreta
    CM. Do morphometrics and allozymes reliably distin-
    guish Africanized and European Apis mellifera drones
    in subtropical Mexico, IBRA. J. Apic. Res. 2001;40:17-
    23.
30. McMullen JB, Brown MJF. The influence of small- cell
    brood combs on the morphometry of honeybees (Apis
31. Meixner M. Interspecific taxonomy of honey bees from
    Austria, Slovenia and Northern Italy carried out with
32. Meixner DM, Miroslaw W, Jerzy W, Fuchs S, Nikolaus
    K. Apis mellifera mellifera range in eastern Europe –
    morphometric variation and determination of its limits.
33. Miguel I, Baylac M, Iriondo M, Manzano C, Garnery,
    Estonba A. Both geometric morphometric and micro-
    satellite data consistently support the differentiation of
    the Apis mellifer A evolutionary branch. Apidologie
34. Miladenovic M, Rados R, Stanisavljevic LZ, Rasic S. Mor-
    phometric traits of the yellow honeybee (Apis mel-
    lifera carnica) from Vojvodina (Northern Serbia). Arch.
35. Milne CP JR, KJ Pries. Honeybee corbicular size and
36. Milne CP JR, Hellmich RL, Pries KJ. Corbicular size in
    workers from honey bee lines selected for high or low
37. Morimoto H. The use of labial palps as a measure of
    proboscis length in worker honeybees, Apis mellif-
    1968;7:147-150.
38. Morris-Olson LS. Aanalys of caste diversification and
    the origin of thelytoky in North American honey bees,
    Apis mellifera (Hymenoptera: Apidae): A morphologi-
    cal perspective. M.Sc. Thesis in Biology, Fac. of Texas
    Tech Univ, 2002.
39. Mostajeran MA, Edriss MA, Basiri MR. Heritabilities and
    correlations for colony traits and morphological charac-
    teristics in honey bee (Apis mellifera meda), Isfahan
    university of technology, 17 th world congress on
    genetic applied to livestocks production, Montpellier,
    France, session 7 August 19-23, 2002
40. Mostajeran MA, Edriss MA, Basiri MR. Analysis of


52. Souza DC, Cruz CD, Campos L, Regazzi AJ. Correlation between honey production and some morphological traits in Africanized honey bees (Apis mellifera). Ciência Rural, Santa Maria 2002;32:869-871.


