Chinese Research Suggests Drones Stimulate Worker Foraging

by Prof. Dr. ZENG ZHI-JIANG and YAN WEIYU
Honey Bee Science Institute, Jiangxi Agricultural University,
Nanchang 330045, Jiangxi, China. Email: bees1965@sina.com

In this paper we studied whether it is the queens or the workers that determine the honey bee sex ratio in Italian Bees. The results showed that the workers determine the ratio of drones to workers, and that drones are not only necessary to mate with the queens, but also stimulate the workers to forage.

The honey bee sex ratio means the proportion of female honey bees (queen and worker) to male honey bees (drone) in the colony. The study of the honey bee sex ratio can help reveal many secrets of honey bees, so we manipulated the honey bee sex ratio artificially in our experiments.

1. Which manipulates the honey bee sex ratio—queen or worker?

The drones die immediately after they mate with the queen and they do not participate in rearing larvae, so it is impossible that the drones participate in manipulation of the honey bee sex ratio. The honey bee sex ratio can be only determined by the queen, the workers, or the queen and the workers together. It has not yet been unequivocally demonstrated.

Dzierzon (1845) presented the famous theory of honey bee sex determination that drones develop from fertilized eggs and queens and workers from unfertilized eggs. Queens can lay fertilized eggs and unfertilized eggs at will with the information of cell size (Flanders, 1950; Ratnieks and Keller, 1998). The possibility of honey bee sex ratio manipulation by the queen was supported by this idea. But this idea was not supported by Sasaki and Obara (1999). Their experiments showed the honey bee queen laid fertilized eggs even when no comb cells for oviposition were available. Charnov et al (1999) suggested that the queen laid eggs with the cue of external conditions in order to determine the sex. This increased the fitness of her offspring to control the sex ratio. Sasaki et al (1996) used the empty checkered frames with the drone and worker cell zones for laying of eggs by the queens and observed the action of oviposition of queens and cleaning cells of workers. The result showed that the queen has the potential ability to adjust the honey bee primary sex ratio (the sex ratio in eggs, larval and pupal stages). At the same time Sasaki et al (1996) suggested that the queen might determine the primary sex ratio on the basis of her own annual rhythm.

Contrary to the evidence of the queen adjusting the honey bee sex ratio, there are other studies suggesting that the workers adjust it. Zhou-song (1983) suggested the sex ratio in the larval stage is not completely determined by the queen's measurement of the cell size, and it may be affected by the behavior information or material information from the worker. Free and Williams (1975) reported that the regulation of the ratio of drones to workers by workers depends not only on the season, but also on the size of the colony. Zeng zhi-jiang considered that the regulation of the sex ratio by workers through their function of cleaning the oviposition cell and rearing the brood is possible. Many writers argue that workers have the potential ability to control the honey bee sex ratio by adjusting the number of drone and worker cells that they build (Allen, 1963; Free and Williams, 1975; Page, 1993). It has been reported that the workers in many ants of Hymenoptera can distinguish the sex of larvae and remove it at will (Aron et al, 1995; Keller et al, 1996; Passera and Aron,1996). In bees, Woyke has demonstrated that workers can discriminate the larvae of diploid males and remove them from cells. Ratnieks and Visscher (1989) showed that workers can discriminate worker-laid male eggs and remove them. And, workers have the ability to discriminate between their full and half sisters (egg, larval and pupal stage) using genetically based labels (such as morphological characters and odors) (Getze and Smith, 1983).

Trivers and Hare (1976) proposed that the animal sex ratio should be studied with the combination of Fisher's Sex Ratio theory and Hamilton's Kin Selection theory and predicted that a conflict between the workers and the queen in manipulating the honey bee sex ratio exists. According to Fisher's Sex Ratio theory and Hamilton's Kin Selection theory, Zeng zhi-jiang et al (1998) calculated the theoretical sex ratio of the queen as 1:1 and workers from 21.5 to 53.9:1 (the average is 37.7:1). But, in fact, the sex ratio of their experimental colonies was from 22.7 to 31.2:1, the average was 26.1:1. It is obvious that the theoretical sex ratio expected for workers is closer to the actual sex ratio. So, it was deduced that the bee sex ratio was determined by workers.

2. The role that drones play in the colony should be re-examined.

The traditional viewpoints suggest that the function of drones in the colony is mating with virgin queens only. But the observations in raising bees showed that during the honey flow season some drones existing in the colony is the sign of a strong colony. Zeng zhi-jiang et al studied the effect of the honey bee sex ratio to the production, reproductive capacity, colony swarming and so on. The result showed that there is no significant difference in the production of royal jelly, reproductive capacity, swarming and colony population between group I (the group which had sealed drone cells cut out, no drones in colony, no sex ratio) and group II (the group where sealed drone cells were not cut out, some drones in colony, sex ratio

exists). However, the honey production, ratio of workers leaving honeycombs and initiation of pollen foraging in group II was higher than those in group I at 8.40%-14.04%, 17.10%-23.50% and 23.80%-26.50%, respectively. Analyzing the reason, we believe that the colony can reach a dynamic balance when there are some proportion of drones in colony, thus the initiation of worker foraging can be stimulated (Zeng et al, 1998,1999). Moreover, we found that external and internal colony conditions can keep the sex ratio in dynamic balance itself and drones do not run wild (Zeng et al, 2000).

This proves the function of drones is not only mating with virgin queens, but also stimulating workers to leave combs for foraging.

Acknowledgments

We thank Prof. S. Zhou for technical advice and Dr. K. Sasaki for providing data. This research was supported by the National Natural Science Foundation of China (No. 30160068 and No. 30310103003).

References

Allen, M. D. 1963. Drone production in honey bee colonies (*Apis mellifera* L.). *Nature*, 199:789-790.

Aron, S. E. V., Passsera, L. 1995.Initial and secondary sex ratios in monogyne colonies of the fire ant. *Anim.Behav*,. 49:749-757.

Charnov, E. L., Los-den Hartogh R L, Jones, W. T., et al. 1987. Sex ratio evolution in a variable environment. *Nature*, 289: 27-33.

Flanders, S .E. 1950. Control of sex in the honey bee. *Scientific Monthly*, 70:237-240.

Free, J. B., Williams, I. H. 1975.Factors determining the rearing and rejection of drones by the honey bee colony colonies (*Apis mellifera* L.). *Anim. Behav.*, 23:650-675.

Getz, W. M., Smith, K. B.1983. Genetic kin recognition: honey bees discriminate between full and half sisters. *Nature*, 302:147-148.

Keller, L., Aron, S., Passera, L. 1996. Internest sex ratio variation and male brood survival in the ant. *Behavioral Ecology,* 3:292-298.

Page, R.E., Fondrk Jr M K, Robinson, G. E. 1993.Selectable components of sex allocation in colonies of the honey bee (*Apis mellifera* L.). *Behavioral Ecology*, 3:239-245.

Ratnieks, F. L., Kvesscher, P. 1983. Worker policing in the honey bee. *Nature*, 342:796-797.

Ratnieks, F. L., Keller, M. L. 1998. Queen control of egg fertilization in the honey bee. *Behav. Ecol. Socibiol.*, 44:57-61.

Sasaki, K., Satoh, T., Obara, Y. 1996.The honey bee queen has the potential ability to regulate the Primary Sex ratio. *Appl. Entomol. Zool*., 2:247-254.

Sasaki, K., Obara, Y. 1999. Honey bee queens lay fertilized eggs when no comb cells for oviposition are available. *Zoological Science*, 16:735-737.

Zeng, Z.J.,Chen,G.. 1998. Study on sex ratios of honey colony. *Journal of Bee*, 4:3-5.

Zeng, Z.J., Xiong, H.H., Guo,D.S.,et al. 1998.Study on the effect of bee sex ratios in the colony productivity. *Apiculture of China*, 1:3-5.

Zeng, Z.J., Guo, D.S., Xiong,H.H., et al. 1999. Study on the effect of bee sex ratios in the colony reproductive capacity and swarming. *Acta Agriculturae Universitatis Jiangxiensis*, 21:282-284.

Zeng, Z.J., Guo, D.S., Wu, G.S., et al. 1999. Study on the effect of bee sex ratios on the population of a colony. *Acta Agriculturae Universitatis Jiangxiensis*, 21: 285-287.

Zeng, Z.J., Wu, G.S., Zhang, Z.Y., et al. 2000. Effects of drone excised on the colony productivity, reproductive capacity and swarming. *Journal of Zhejiang University (agric. and life science)* 26:540-542.

Zhou,S. 1983. Honey bee procreation. *Biology Bulletin of China*, 5:13-15.