Colony development and queen rearing in Kenyan honey bees - Apis mellifera scutellata (2002)

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Introduction

For successful managing and rearing of honey bees it is imperative to adapt beekeeping measures to colony development. The annual cycle of colony development of European honey bee (*Apis mellifera*) colonies is described in detail in many independent studies in temperate climates from North America (Farrar, 1937; Avitabile, 1978), Europe (Wille and Gerig, 1976; Liebig, 1996) and Asia (Gong, 1980). Under temperate conditions, the colony brood rearing cycle is characterized by complete cessation of brood rearing in the late fall and reduction of colony size during the winter (Avitabile, 1978). Limited brood rearing may be initiated already during winter months and brood rearing leading to colony expansion is often initiated already before nectar and pollen become available (Seeley, 1978).

In tropical or neo-tropical climates, where honey bees are able to rear brood continuously throughout the year, data on colony development is much more scarce. Africanized bees in tropical South America rear brood throughout the year, but reduce amount of brood reared during the rainy season (Winston, 1980). Compared to honey bees in temperate climates, colonies may respond more rapidly with increased brood rearing when foraging conditions become favorable (Rinderer and Hellmich, 1991). In a detailed comparison between Africanized honey bees and European honey bees in Yucatan, Mexico, it was found that both types of bees produced approximately the same amount of brood although the peak of production was earlier for the Africanized bees (Echazarreta and Paxton, 1997). It has been suggested that Africanized honey bee colonies generally contain larger amounts of brood compared to European honey bees (Spivak, 1992). Nevertheless, it seems that the absolute amount of worker brood recorded in Africanized honey bees in the neo-tropics at any one point in time (c. 3850 cm2), is similar to recordings from honey bees in temperate climates (Echazarreta and Paxton, 1997).

Data available on the annual cycle of colony development of honey bees of sub-Saharan African descent is limited to South America (Echazarreta and Paxton, 1997) and South Africa (Anderson, 1977). From East Central Africa, there is virtually no information available on the poulation dynamics of either wild or managed honey bee colonies. It is known that the egglaying capacity of at least some African bees exceeds that of European bees (Fletcher, 1978), but population dynamic studies that include both bees and brood production is lacking. For the development of appropriate beekeeping management strategies using modern moveable frame hives such information is needed. Furthermore, queen rearing is essential for improving existing stock, but has not been practiced successfully with African bees in spite of many attempts (Fletcher and Tribe, 1977).

This paper reports on population dynamic measurements in honey bee colonies (*Apis. mellifera scutellata*) outside Nairobi, Kenya, and on queen cell acceptance after grafting throughout the year with the objective to collect data on colony development and queen rearing possibilities in the studied region.

Material and Methods

Climate

Due to the high altitude (about 1600 m above sea-level), the climate at the study site outside of Nairobi, Kenya is pleasant, in spite of the location close to the equator, S01°13'E036°95'. The yearly average of the highest temperature ranges between 21°C to 27°C and the yearly average of the lowest temperature ranges between 12-16 °C. June July and August is the coolest period of the year. In general, there is a high rain season in April and May, and a low rain season in November and December.

Colony population dynamics

Four honey bee colonies were randomly chosen from the ICIPE (International Center for Insect Physiology and Ecology) apiary about 20 km northeast of Nairobi, Kenya, for population dynamic studies. All colonies had laying *A. mellifera scutellata* queens, (cubital index 2,56 + 0.07 (n=100) in compliance with *A. mellifera scutellata*, morphology (Ruttner, 1988)) and were kept on standard Langstroth equipment using full debth frames and given space according to need. At the start of registration the colonies consisted of between 5000-10000 bees and had approximately 7, 000-10,000 sealed brood cells each. Colony records prior to this study made evident that foraging conditions at the study site did not support colony growth throughout the year due to nectar shortage. Thus, colonies were supplied weekly with approximately 2 liter 1:1 sugar solution throughout the study period in bottom board feeders. No pollen additives were used as pollen supply was more or less continuously present. From late August 1996 to late August 1998 colonies were monitored for population changes and brood rearing dynamics at irregular (mostly between 2-4 weeks) intervals. The area of sealed brood, open brood (larvae) and eggs were estimated using the Liebefeld method (Gerig, 1983) where the proportion of each combside occupied by each brood category is evaluated. To determine the number of cells occupied by sealed brood, open brood and eggs when using the Liebefeld method, it is necessary to know the number of cells per area unit. The size of the cells in African bee races are distinctly smaller than those of European bee races and may vary considerably (Hepburn and Radloff, 1998). To determine the number of cells per dm2 in the experimental colonies, 6 samples of wax of 4 x 4 cm from 6 different colonies were measured and the average number of cells per cm2 was used to calculate the number of cells occupied by each respective brood type.

The Liebefeld technique was found unsuitable for estimation of the bee strength due to the aggressive behavior of the bees under study, with a large proportion of the bees in the air after a short period of keeping the hives open for inspection. Thus, the bee strength evaluations should be considered as rough estimates of population fluctuations only.

To monitor if all eggs laid by the queen survived and resulted in sealed brood, three of the four colonies used for brood rearing dynamics were studied more closely. Around 100 cells where eggs had been deposited were marked on a plastic film. After two weeks these marked films were used to document if the eggs laid had resulted in sealed brood. The registration of eggs/larvae removal were conducted from late September 1997 to late September 1998 with approximately 2-4 week intervals, but with no registration in December-January.

Queen cell acceptance

Queen cell rearing was prepared using both queen-less and queen-right colonies (cell raising colonies),using 6-8 combs fully occupied by bees (approximately 10000-12000 bees (Burgett and Burikam, 1985) Queen-less colonies was prepared 24 h. prior to grafting of the selected larvae, by moving the queen along with 3 combs to an adjacent empty hive making the mother colony queen-less. The grafted cells were put directly into the middle of the cell raising colonies and additional sugar syrup were fed when there were no nectar flow. The queen-right colonies were prepared to receive grafted cells one day before grafting. The queen was confined to the brood box by a queen excluder and a super containing combs with honey, pollen and both sealed and open brood was placed above the queen excluder. The bar containing grafted larvae in cell cups was placed between brood combs in the upper box. Additional sugar syrup were fed when there were no nectar flow. For grafting, larvae less than 24 h. old were transferred to dry wax cell cups melted onto a wooden bar. Each grafting consisted of 30 cells. The grafted larvae were introduced into either a queen-less or a queen-right cell raising colony. The results from 79 graftings were recorded with 59 in queen-right cell raisers (May 1996 to March 1998) and 20 in queen-less cell raisers (June 1996 to Dec. 1997). Fourteen of the grafts were mad, parallel on the same day in both types of cell raisers (June 1996 to Dec. 1997). Queen cell acceptance was registered 3 days post grafting. The cell was registered as accepted when the grafted larva were fed and remained in the cell.

Results

The measured number of cells per dm2 was 457 ±14,5 (N=6).

In figure 1 the calculated number of cells with sealed brood, larvae and eggs during the studied period can bee seen. In figure 1-a to 1-c the registrations for each parameter are graphed separately with their S. D. In figure 1-d the numbers of all parameters are compared using the same scale The brood area seems to increase during the first and second quarter of the year but begin to rapidly decline at the end of the second quarter and during the third quarter, to start expanding again during the fourth quarter.

In figure 2 the proportion of brood produced by the queen but removed by the bees before sealing in three colonies is presented.

Covering all grafting dates, the acceptance rate is significantly higher in queen-less colonies ($P<0.05$ paired t-test, 13 df) with an average acceptance rate of 0.202 for queen-less colonies and 0.096 for queen-right colonies. Although the acceptance rate was higher in queen-less colonies the queen-less system where colonies were split to produce the queen-less unit was more difficult to manage due to absconding behavior (Hepburn, H. L. et al. 1999). The queen-right part of the split frequently absconded with subsequent loss of both the queen and the bees. Because of the difficulty to maintain A. m. scutellata colony splits and because the queen-right system is easier to work with, most graftings in the present study has been made into queen-right colonies. The acceptance rate of all grafts in queen-right colonies is presented in Table I.

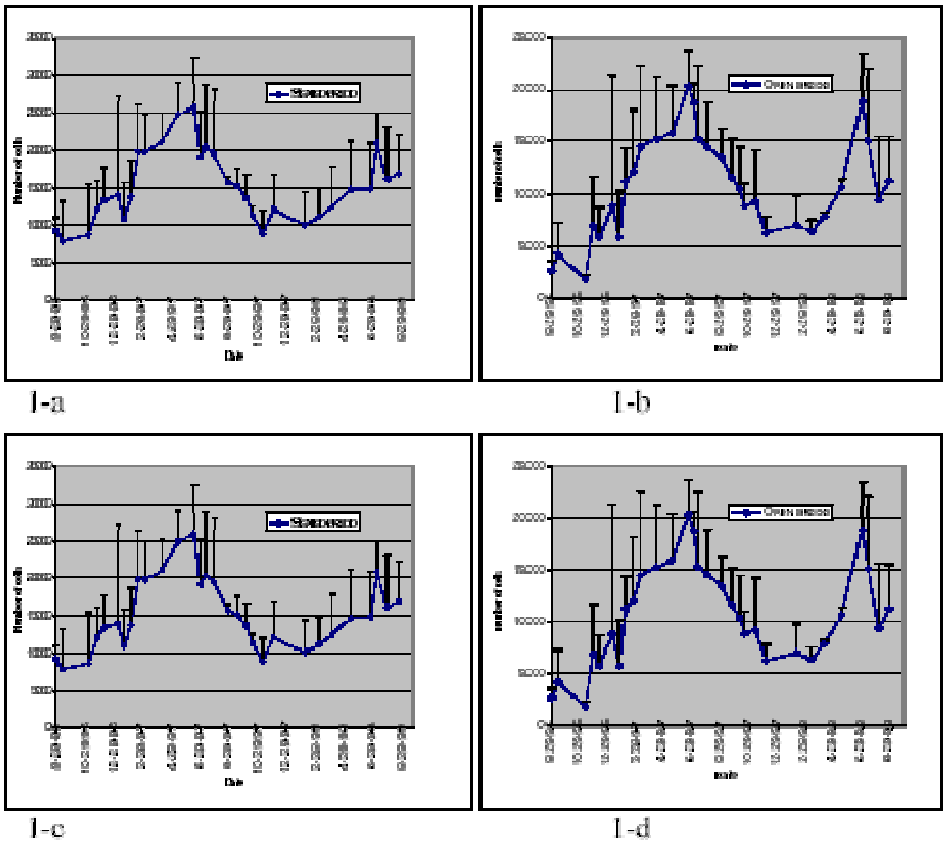

Figure 1: The develop-patterns of sealed brood, open brood and eggs during the study period (Aug. 1996 to Aug. 1998).

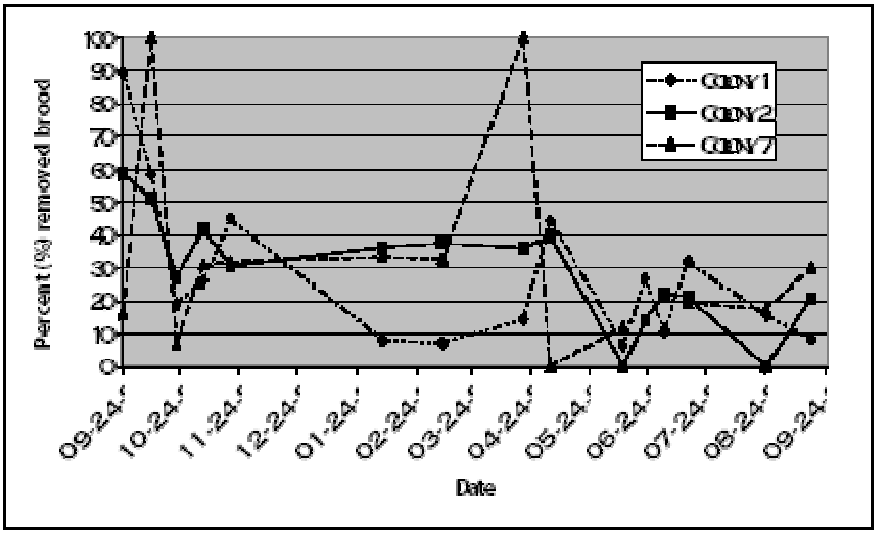

Figure 2: Proportion of removed brood in three observed colonies.

First quarter		Second quarter		Third quarter		Fourth quarter	
Grafting date	Rate of cell acceptance	Grafting date	Rate of cell acceptance	Grafting date	Rate of cell acceptance	Grafting date	Rate of cell acceptance
97-01-21	0,42	96-05-24	0,13	96-07-03	0	96-10-09	0
97-02-19	0,45	96-05-29	0,66	96-07-07	0,26	96-10-15	0,41
98-01-07	0,45	96-06-07	0,13	96-08-22	0	96-10-16	0,60
98-01-20	0	96-06-11	0	96-08-29	0	96-10-17	0,32
98-01-21	0	96-06-19	0,11	96-09-06	0,09	96-11-04	0
98-02-06	0	97-05-20	0,13	96-09-20	0,20	96-11-07	0,14
98-02-17	0	97-06-17	0,07	96-09-18	0	96-11-29	0,03
98-02-18	0	97-06-23	0	97-07-03	0	97-10-14	0
98-02-24	0,10	97-06-24	0	97-07-09	0	97-11-04	0,20
98-02-25	0	97-06-30	0	97-07-10	0	97-11-14	0,20
98-03-02	0	98-04-07	0,07	97-07-11	0	97-12-05	0
98-03-03	0,50	98-06-04	0,30	97-07-14	0	97-12-09	0,79
98-03-05	0,10	98-06-24	0,70	97-07-16	0		
98-03-11	0,25			97-08-12	0,20		
98-03-17	0,53			97-09-11	0		
98-03-23	0,20			97-09-26	0		
				98-07-13	0,23		
				98-07-27	0,40		
Average	0,19		0,18		0,08		0,22

Table I. Rate of queen cell acceptance at different dates divided into the four quarters of the year. Grafting into dry wax cell cups introduced into queen-right cell raising colonies

Discussion

The colony development pattern seems at least partly to be associated with the weather conditions with a brood area increase when the rain seasons start and with a general reduction as the weather cools off in July and August (Figure 1). Although the studied colonies were continuously fed sugar solution they failed to grow into what could be considered large colonies (more than 30.000 bees) under European conditions. The bee colonies never occupied more than 10 combs and the bee populations probably never exceeded 30 000 bees. The population measurements should be considered rough estimates due to the difficulties in estimating number of bees in a colony when a large part of the population is in the air. Even at dusk such estimates are difficult to make since African bees need less light for flight compared to European bees (Fletcher and Tribe, 1977). The brood production could be estimated more accurately than the bee population and substantial amounts of brood were produced. From figure 1, it can bee seen that the sealed brood and larvae seem to peak in May-June to be at the lowest intensity during November-January under the prevailing conditions. The maximum average number of sealed brood cells in this investigation (~ 26,000) is larger than reported for Africanized bees in Mexico (~14,000) data extracted from figure 1 (Echazarreta and Paxton, 1997), but slightly lower than reported from the only available all year registration from A. mellifera scutellata (from South Africa, 28000) data extracted form figure 1 (Anderson, 1977). Figure 1 indicates that the temporal variation in sealed brood area is larger than the variation in production of eggs by the queen. Obviously, the queen is continuously producing a large number of eggs under the prevailing conditions, but only a varying proportion of these eggs seem to mature into sealed brood and finally into adults.

The high rate of removal of immature brood could partly explains the relatively small sized colonies. The low brood survival in the present experiment may indicate pollen deficiency, although some level of pollen foraging was always available (bees carrying pollen was always present during foraging). Woyke (1977) found the brood survival to be greatly dependent on the foraging condition of African bees, in particular pollen shortage resulted in low brood survival (Woyke, 1977). It should be tested if feeding pollen substitutes would increase brood survival in the test apiary and, thus, produce larger colonies.

Although queen fecundity is equal to or even larger compared to European bees, tropical honey bee races nevertheless have smaller colonies compared to races in temperate climates (Winston, 1987). Besides cannibalism during periods of dearth (Woyke, 1977), both smaller sized bees and the shorter life-span of tropical bee races may help to explain that colonies of European bees in temperate climates generally require more space (Winston, 1979).

The queen cell acceptance in this study is generally low both in queen-right and queen-less cell rearing colonies. The queen cell acceptance is significantly higher, but still low, in queen-less starter colonies. Because of the difficulties in maintaining queen-less colonies of *A. mellifera scutellata*, it is probably still more advantageous to look for improvements in acceptance rate in queen-right colonies by altering the grafting system and/or colony management. It should be tested if priming of cells using royal jelly prior to grafting, as well as supplementary feeding of pollen to the cell raising colony, will influence the queen cell acceptance rate. In spite of the generally low acceptance of queen cells in this study, the presented data still indicates a higher success rate in queen rearing during periods with expanding brood rearing. Although the amount of brood is substantial in the studied colonies during the third quarter of the year (figure 1), it is decreasing. During this period with decreasing brood rearing, the acceptance rate of queen cells is particularly low, compared to when there is an increase (first, second and fourth quarter, figure 1, Table I).

For measurements of African honey bee population dynamics and evaluations for bee production capacities, studies should be conducted at sites with more favorable general conditions than in the present study. In spite of these shortcomings, a brood rearing pattern emerges that indicats what part of the year, queen rearing should be most favorable. Undoubtedly, successful queen rearing can be accomplished also with *A. mellifera scutellata*, something necessary if improvement of their temperament is sought for. Although the acceptance rate of queen cells was low in our experiments, we demonstrate that methods used for queen rearing in European races of *A. mellifera* can be used also on African honey bees. Efforts should be made to find how existing queen rearing methods could be adjusted to increase success rate in grafting results as well as investigations of optimal systems for hatching and mating queens under African conditions.

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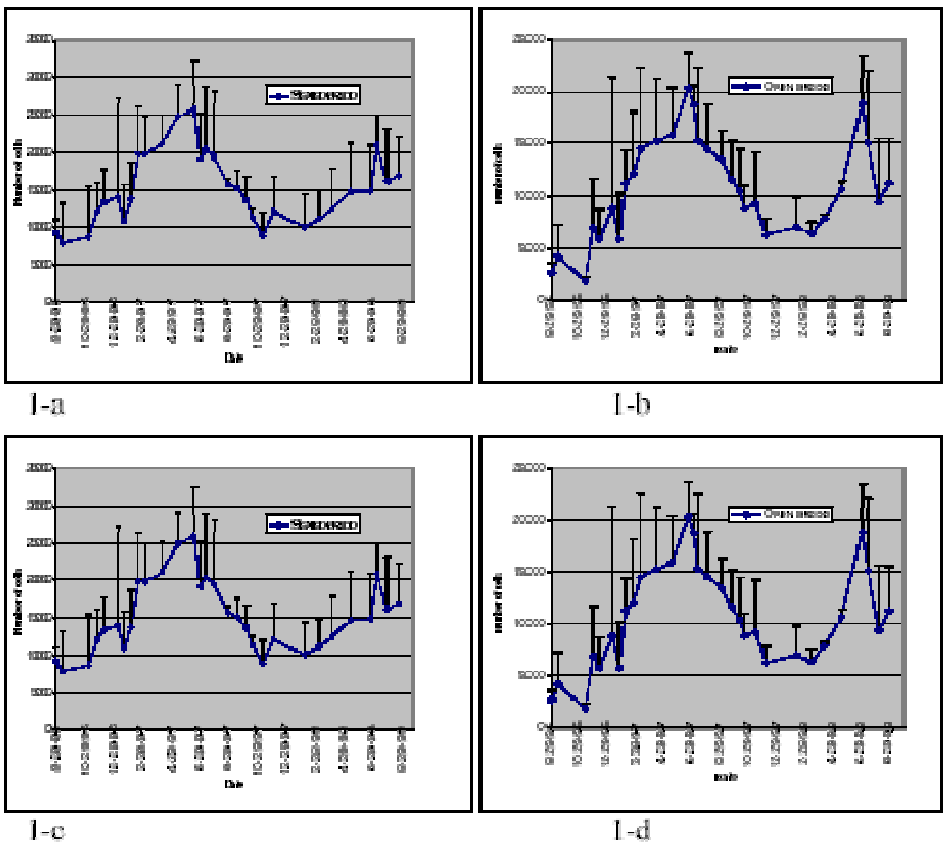

I-a I-b

I-c I-d

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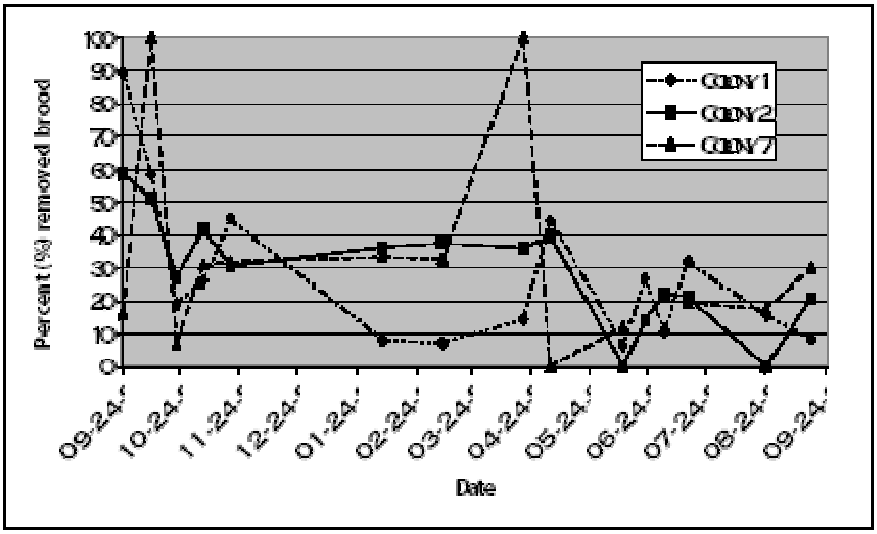

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98-01-20	0	96-06-11	0	96-08-29	0	96-10-17	0,32
98-01-21	0	96-06-19	0,11	96-09-06	0,09	96-11-04	0
98-02-06	0	97-05-20	0,13	96-09-20	0,20	96-11-07	0,14
98-02-17	0	97-06-17	0,07	96-09-18	0	96-11-29	0,03
98-02-18	0	97-06-23	0	97-07-03	0	97-10-14	0
98-02-24	0,10	97-06-24	0	97-07-09	0	97-11-04	0,20
98-02-25	0	97-06-30	0	97-07-10	0	97-11-14	0,20
98-03-02	0	98-04-07	0,07	97-07-11	0	97-12-05	0
98-03-03	0,50	98-06-04	0,30	97-07-14	0	97-12-09	0,70
98-03-05	0,10	98-06-24	0,70	97-07-16	0		
98-03-11	0,25			97-08-12	0,20		
98-03-17	0,53			97-09-11	0		
98-03-23	0,20			97-09-26	0		
				98-07-13	0,23		
				98-07-27	0,40		
Average	0,19		0,18		0,08		0,22

Table I. Rate of queen cell acceptance at different dates divided into the four quarters of the year. Grafting into dry wax cell cups introduced into queen-right cell raising colonies

Discussion

The colony development pattern seems at least partly to be associated with the weather conditions with a brood area increase when the rain seasons start and with a general reduction as the weather cools off in July and August (Figure 1). Although the studied colonies were continuously fed sugar solution they failed to grow into what could be considered large colonies (more than 30.000 bees) under European conditions. The bee colonies never occupied more than 10 combs and the bee populations probably never exceeded 30 000 bees. The population measurements should be considered rough estimates due to the difficulties in estimating number of bees in a colony when a large part of the population is in the air. Even at dusk such estimates are difficult to make since African bees need less light for flight compared to European bees (Fletcher and Tribe, 1977). The brood production could be estimated more accurately than the bee population and substantial amounts of brood were produced. From figure 1, it can bee seen that the sealed brood and larvae seem to peak in May-June to be at the lowest intensity during November-January under the prevailing conditions. The maximum average number of sealed brood cells in this investigation (~ 26,000) is larger than reported for Africanized bees in Mexico (~14,000) data extracted from figure 1 (Echazarreta and Paxton, 1997), but slightly lower than reported from the only available all year registration from A. mellifera scutellata (from South Africa, 28000) data extracted form figure 1 (Anderson, 1977). Figure 1 indicates that the temporal variation in sealed brood area is larger than the variation in production of eggs by the queen. Obviously, the queen is continuously producing a large number of eggs under the prevailing conditions, but only a varying proportion of these eggs seem to mature into sealed brood and finally into adults.

The high rate of removal of immature brood could partly explains the relatively small sized colonies. The low brood survival in the present experiment may indicate pollen deficiency, although some level of pollen foraging was always available (bees carrying pollen was always present during foraging). Woyke (1977) found the brood survival to be greatly dependent on the foraging condition of African bees, in particular pollen shortage resulted in low brood survival (Woyke, 1977). It should be tested if feeding pollen substitutes would increase brood survival in the test apiary and, thus, produce larger colonies.

Although queen fecundity is equal to or even larger compared to European bees, tropical honey bee races nevertheless have smaller colonies compared to races in temperate climates (Winston, 1987). Besides cannibalism during periods of dearth (Woyke, 1977), both smaller sized bees and the shorter life-span of tropical bee races may help to explain that colonies of European bees in temperate climates generally require more space (Winston, 1979).

The queen cell acceptance in this study is generally low both in queen-right and queen-less cell rearing colonies. The queen cell acceptance is significantly higher, but still low, in queen-less starter colonies. Because of the difficulties in maintaining queen-less colonies of *A. mellifera scutellata*, it is probably still more advantageous to look for improvements in acceptance rate in queen-right colonies by altering the grafting system and/or colony management. It should be tested if priming of cells using royal jelly prior to grafting, as well as supplementary feeding of pollen to the cell raising colony, will influence the queen cell acceptance rate. In spite of the generally low acceptance of queen cells in this study, the presented data still indicates a higher success rate in queen rearing during periods with expanding brood rearing. Although the amount of brood is substantial in the studied colonies during the third quarter of the year (figure 1), it is decreasing. During this period with decreasing brood rearing, the acceptance rate of queen cells is particularly low, compared to when there is an increase (first, second and fourth quarter, figure 1, Table I).

For measurements of African honey bee population dynamics and evaluations for bee production capacities, studies should be conducted at sites with more favorable general conditions than in the present study. In spite of these shortcomings, a brood rearing pattern emerges that indicats what part of the year, queen rearing should be most favorable. Undoubtedly, successful queen rearing can be accomplished also with *A. mellifera scutellata*, something necessary if improvement of their temperament is sought for. Although the acceptance rate of queen cells was low in our experiments, we demonstrate that methods used for queen rearing in European races of *A. mellifera* can be used also on African honey bees. Efforts should be made to find how existing queen rearing methods could be adjusted to increase success rate in grafting results as well as investigations of optimal systems for hatching and mating queens under African conditions.

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