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ORIGINAL ARTICLE

Comparative study for evaluating two honey bee races, *Apis mellifera jementica* (indigenous race) and *Apis mellifera carnica* (carniolan race) in brood production, population development and foraging activity under the environmental conditions of the central region of the Kingdom of Saudi Arabia

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Abstract This field study was carried out to evaluate two honeybee races namely; *Apis mellifera jementica* (indigenous race) and *Apis mellifera carnica* (carniolan race) based on brood production, population development, foraging activity, and queens status through the experimental period extended from March, 2009 up to March, 2010 under main physical environmental conditions of the central region of the Kingdom of Saudi Arabia. The obtained results showed that, indigenous bees transferred from traditional hives (Aoud) into Langstroth (modern) hives and supplied with frames contained 33 cells/μ^2 (regular worker-size cell for indigenous bees) (group I) had significantly higher brood production and population development than indigenous bees transferred from traditional hives into Langstroth hives and supplied with frames contained 25 cells/μ^2 (regular worker-size cell for European bees) (group II) and carniolan bees transferred from honey bee nuclei into Langstroth hives and supplied with frames contained 25 cells/μ^2 (regular worker-size cell for European bee) (group III). The general mean of brood area in cm^2, frames of brood and frames covered with adult

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bees were (2813.13, 1730.94 and 1867.05 cm^2/colony), (3.13, 2.21 and 2.07 brood comb/colony) and (6.39, 4.44 and 4.38 comb of bees/colony), in groups I, II and III, respectively. The indigenous race significantly surpassed the carniolan race in brood production during summer season during high temperature commonly exceeds 45 °C. Data also showed that no significant difference in foraging activity between the two examined races (indigenous and carniolan race) for gathering pollen during the first inspection period extended from 6 to 7 am during the relatively cold, moderate and very high air temperature during inspection months. This situation differed between the two examined races during the second and third inspection period extended from 11 to 12 am and 4 to 5 pm, relatively high air temperature in June, August and October, during which the indigenous race significantly surpassed the carniolan race in foraging activity for gathering pollen. Moreover, the foraging activity was significantly higher in the first inspection period (6–7 am) than the other two periods (11–12 am and 4–5 pm). When the numbers and percentages of died or superseded queens in the three inspection groups (I, II and III) were studied, no died or superseded queens were found in honey bee colonies in group (I) during the experimental period which was extended from March, 2009 to March, 2010. However, the percentages of failed queens during the experimental period were 0.00%, 45.00% and 60.00% in groups (I, II and III), respectively. The results also showed that increasing the size of the worker cells negatively affected brood production and population density in indigenous race and indigenous race is more tolerant and well adapted to the environmental conditions in the search area than carniolan race (imported). Therefore, this study recommends that improving the characteristics of indigenous and carniolan races should take place through breading programs, because the indigenous race shows high ability and good adaptation to the environmental conditions in the area but it is small in size, in addition their honey stomach and pollen basket are small, meanwhile the carniolan race is large in size and their honey stomach and pollen basket are great, but is not acclimatized to environmental conditions in the region, especially during the hot summer when the air temperature exceeds 45 °C.

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Introduction

There are two honey bee races commonly found in the Kingdom of Saudi Arabia; the indigenous bees (*Apis mellifera jementica*) and the carniolan bees (*Apis mellifera carnica*). The indigenous race is widely spread in many parts of Saudi Arabia, in particular the west, south west and south parts, most of the carniolan race is found in the north, east and center parts of the kingdom. The majority of carniolan race is imported from Egypt. On the other hand, most of the beekeepers in Saudi Arabia prefer to raise the indigenous bees in traditional hives (it calls Aoud). The Ministry of Agriculture in Saudi Arabia conducted a survey in 2009 on number of the beekeepers, traditional and modern hives, and the ratio between the indigenous and European races. The survey results revealed that the indigenous race which was raised in traditional hives represented about 92.43% and carniolan race which was raised in Langstroth (modern) hives represented about 7.57%. It was also found that traditional hive yielded about 1.8 kg/colony/year. Meanwhile Langstroth hive yielded about 3.3 kg/colony/year. For this reason, many beekeepers have been started transferring their indigenous bees from traditional hives into Langstroth hives to improve their characteristics and production features.

The productivity of honey bee colonies throughout the year is influenced by different factors, particularly egg laying capacity, colony population and empty combs as well as the climatic factors and supply of both pollen and nectar (Corbet et al., 1993; Abdella, 1996; Ali, 2007). On the other hand, among the abiotic factors, temperature has been found to be the most important that governs honeybee activities, especially queen's egg laying and brood production (Rachad and Parker, 1958; Corbet et al., 1993; Dag and Eisikowitch, 1999; Gary, 1999; Abrol, 2006). Heinrich (1996) stated that honey bees are able to forage over a 30 °C range of air temperature largely because they have behavioral and physiological mechanisms for regulating the temperature of their flight muscles. Meanwhile, Gary (1999) found that the minimum temperature needed for active foraging for European honeybees was approximately 13 °C. He also concluded that above 43 °C nectar and pollen foraging were ceased but water foraging was continued. Alqarni (2006) in Saudi Arabia found that the indigenous race (*A.m. jementica*) had significantly lower weight loss than the carniolan and Italian races during summer season. Nagi Siham (1990) found that the first carniolan hybrid surpassed their parents in brood production and pollen gathering, followed by the pure indigenous race, then the pure carniolan race in Sudan. Silva and De Jang (1990) conducted a study in Brazil on Africanized and European honey bees in foraging activity. They found that Africanized bees had three foraging beaks, during the day, between 7 and 8 am, 2 and 3 pm and 3 and 5 pm, whereas the European bees had three foraging period, between 9 and 10 am, 11 and 12 am and 3 and 4 pm. Guzmán-Becerra et al. (2005) found that European bees had longer foraging life than Africanized bees. Abrol (2010) studied the foraging behavior in relation to five environmental parameters; it was concluded that the foraging population correlated significantly and positively with air temperature, light intensity, solar radiation and nectar-sugar concentration and negatively with relative humidity.

The aim of the current study is to evaluate two honeybee races namely; *A.m. jementica* (indigenous race), and *A.m. carnica* (carniolan race) for brood production, population development, foraging activity and queen status under the physical environmental conditions of the central region of the Kingdom of Saudi Arabia. It also aimed to evaluate queen status in brood production and population development, as well as queen superseding in indigenous race when transfered them from their traditional hives to Langstroth (modern) hives which were supplied with empty frames contained 33 worker-size cell/μ^2 (regular cell size for indigenous bee) and empty combs contained 25 worker cells/μ^2 (regular cell size for European bees).

Materials and methods

The present field experiment was carried out on honey bee colonies, *A.m. jementica* (indigenous race) and *A.m. carnica* (carniolan race) during the experimental period extended from March, 2009 to March, 2010 at Queen Rearing and Honeybee Nuclei Production Station, Agricultural Extension Department, Ministry of Agriculture, Riyadh, Kingdom of Saudi Arabia.

Honeybee races

Sixty honey bee colonies headed by newly-pure mated queens were prepared for this study; they were divided into three different groups as follows:

Group (I)

Contained 20 honey bee nuclei headed by newly-pure mated indigenous queens (*A.m. jementica*), transferred from traditional hives (Aoud) into Langstroth (modern) hives and supplied with empty combs contained 33 worker-size cells/μ^2 (regular cells for indigenous race).

Group (II)

Contained 20 honeybee nuclei headed by newly-pure mated indigenous queens (*A.m. jementica*), transferred from traditional hives into Langstroth hives and supplied with empty combs contained 25 worker-size cells/μ^2 (regular cells for European race).

Group (III)

Contained 20 honeybee nuclei headed by newly-pure mated carniolan queens. The nuclei were transferred into Langstroth hives and supplied with empty combs contained 25 worker-size cells/μ^2 (the regular cells for European race).

Each honey bee nucleus contained about five frames covered with adult bees, three frames of sealed brood, two honey and pollen combs, and newly-pure mated queen). They were monitored by feeding them with pollen cake and sugar sirup at 10-days intervals during dearth period (Mladenovic et al., 2002; Ali, 2007), and they were treated against varroa disease during the experiment period.

Traditional hive (aoud)

It is used for raising the indigenous bees in most parts of Arabic Gulf countries including Saudi Arabia. It is built from wood or clay; it is cylindrical in shape about, 25–30 cm from inside, and its length about 50–120 cm. It contains about 15–25 fixed-circle combs, the number of worker cells/μ^2 about 33 worker-size cells/μ^2. The bees build their circle combs by themselves. The beekeepers name this hive Aoud.

Honeybee colony strength

The following parameters were measured for colony strength.

Brood area in cm²

Square centimeters of brood were measured for experimental honey bee colonies by using a measuring sheet (modified from Jeffree, 1958).

Frames of brood survivors and frames of bees

Number of frames relatively covered with adult honey bees and frames of brood in experimental colonies were counted and recorded.

The brood production and population development for experimental colonies were measured and recorded monthly during the experiment period extended for one year.

Foraging activity

Six honey bee colonies from each race (indigenous and carniolan races) were selected for studying foraging activity. The foraging activity was estimated three times/day at 5–6 am, 11–12 am and 4–5 pm. The number of foragers was recorded visually by a counter and it was repeated during different seasons. The foragers were estimated by counting all workers introduced into their hives and those introduced into their hives loaded with pollen grains on their legs for 10 min.

Queen status

The number of died and superseded queens in all the experimental colonies for three groups were counted and recorded during the experiment period which was extended from March, 2009 to March, 2010.

Experimental design and analysis

The experimental design was a completely randomized design. Results were analyzed, using SAS (SAS Institute, 2006). The general linear modules procedure to test for differences (alpha = 0.05) and the application of the least significant differences as a mean separation test were used.

Results

Brood area in cm²

Data given in Table 1 showed square centimeters of brood in the experimental colonies in different groups. Data showed that no significant difference in brood area in cm^2 between the three groups at the beginning of the experiment, during March (F = 4.15, df = 59, P = 0.0369). In April honey bee colonies in groups (I and III) had significantly high brood area, meanwhile colonies in group (II) had significantly less brood area (F = 17.22, df = 59, P = 0.0001). During May, honey bee colonies in group (I) had significantly high brood production, followed by honey bee colonies in group (III), meanwhile colonies in group (II) had significantly less brood area (F = 150.26, df = 59, P = $<$0.0001). The same trend was obtained during June (F = 64.77, df = 59, P = $<$0.0001).

Table 1 Square centimeters of brood in experimental honeybee colonies in three different groups from March, 2009 to March, 2010 (Mean ± S.E).

Group	n	Square centimeters of brood from March, 2009 to March, 2010													Mean ± S.E
		March	April	May	June	July	August	September	October	November	December	January	February	March	
I	20	1095.00 ± 17.27a	2040.67 ± 30.48a	2922.67 ± 38.96a	3582.67 ± 34.99a	4021.33 ± 29.39a	4146.67 ± 65.42a	4672.67 ± 21.09a	3730.00 ± 83.77a	2831.67 ± 66.17a	870.67 ± 101.90a	776.33 ± 80.80a	1348.67 ± 64.92a	1447.33 ± 74.70a	2813.13 ± 482.41a
II	20	981.67 ± 25.95a	1926.33 ± 34.20b	1659.67 ± 59.29c	2513.00 ± 45.23c	2825.33 ± 45.93b	3008.33 ± 46.17b	3116.67 ± 36.18b	2294.00 ± 128.58b	1593.67 ± 92.49b	324.00 ± 65.46b	327.33 ± 66.02b	203.00 ± 91.16b	264.33 ± 118.86b	1730.94 ± 352.17b
III	20	1068.67 ± 39.69a	2070.33 ± 65.08a	2212.33 ± 54.53b	2823.00 ± 103.75b	2525.67 ± 65.01c	2583.17 ± 53.12c	2425.33 ± 71.19c	2155.67 ± 100.83b	1495.00 ± 54.05b	405.33 ± 138.65b	207.00 ± 92.00b	136.67 ± 86.49b	187.00 ± 118.33b	1867.05 ± 391.56b
L.S.D (0.05)		115.81	145.49	155.69	206.13	147.19	167.19	143.68	319.82	219.08	320.32	242.79	246.11	319.46	232.15

Honey bee colonies in group (I) had significantly high brood area, followed by honey bee colonies in group (II), meanwhile colonies in group (III) had significantly less brood area during July (F = 261.05, df = 59, P = < 0.0001), August (F = 212.44, df = 59, P = < 0.0001) and September (F = 583.14, df = 59, P = < 0.0001). Meanwhile, honey bee colonies in group (I) had significantly high brood area, followed by honey bee colonies in group (II and III), without significant difference between the last two groups during October (F = 67.51, df = 59, P = < 0.0001), November (F = 105.03, df = 59, P = < 0.0001), December (F = 7.70, df = 59, P = < 0.005), January (F = 13.88, df = 59, P = 0.0004), and February (F = 69.65, df = 59, P = < 0.0001). In March, 2010 the same trend was obtained, honey bee colonies in group (I) had significantly high brood area, followed by group (II and III), without significant difference between the last two groups (F = 44.43, df = 59, P = < 0.0001) (Table 1).

The general mean of brood area in cm^2 showed that honey bee colonies in group (I) significantly surpassed the two other groups in brood area (2813.13 cm^2/colony), where it was (1730.94 and 1867.05 cm^2/colony) for colonies in group (II and III), respectively, without significant differences between the last two groups (Table 1).

Frames of brood

Data presented in Table 2 showed that there were no significant differences in number of frames of brood among the three groups (I, II and III) during the spring season in March, April and May (F = 0.00, df = 59, P = 0.000). During summer season honey bee colonies in group (I) had significantly more numbers of frames of brood, followed by groups (II and III) without significant differences between the last two groups, in June (F = 2.33, df = 59, P = < 0.0001), July (F = 133.00, df = 59, P = < 0.0001) and August (F = 157.00, df = 59, P = < 0.0001). In autumn season, honey bee colonies in group (I) had significantly more frames of brood, followed by group (II), meanwhile group (III) had significant less number of frames of brood in September (F = 18.41, df = 59, P = < 0.0001), October (F = 30.79, df = 59, P = < 0.0001) and November (F = 52.80, df = 59, P = < 0.0001). During winter season, honey bee colonies in group (I) had significantly more frames of brood, followed by groups (II and III) without significant differences between the last two groups, in December (F = 7.99, df = 59, P = 0.0043), January (F = 19.75, df = 59, P = < 0.0001) and February (F = 10.68, df = 59, P = 0.0013). During March, 2010 the same trend was obtained, honey bee colonies in group (I) had significantly high frames of brood, followed by group (II and III), without significant difference between the last two groups (F = 13.38, df = 59, P = 0.0005) (Table 2).

The general mean of numbers of frames of brood showed that, honey bee colonies in group (I) significantly surpassed the two other groups (II and III) in mean number of frames of brood (3.13, 2.21 and 2.07 comb/colony), in group (I, II and III), respectively, without significant difference between the last two groups (Table 2).

Frames covered with adult honey bees

Data in Table 3 showed that, at the beginning of the experiment in Spring, there were no significant differences in number of frames covered with adult honey bees between the three

Table 2 Mean number of frames of brood in honey bee colonies in three different groups from March, 2009 to March, 2010 (Mean ± S.E).

Group	n	Frames of brood from March, 2009 to March, 2010													Mean ± S.E
		March	April	May	June	July	August	September	October	November	December	January	February	March	
I	20	1.00 ± 0.00a	2.00 ± 0.00a	2.00 ± 0.00a	3.00 ± 0.00a	3.00 ± 0.08a	3.00 ± 0.17a	4.00 ± 0.00a	4.00 ± 0.08a	4.00 ± 0.00a	3.08 ± 0.08a	2.17 ± 0.11a	2.00 ± 0.00a	3.08 ± 0.08a	3.13 ± 0.05a
II	20	1.00 ± 0.00a	2.00 ± 0.00a	2.00 ± 0.00a	2.08 ± 0.08b	2.08 ± 0.08b	2.00 ± 0.00b	3.25 ± 0.17b	3.50 ± 0.08b	3.08 ± 0.08b	1.75 ± 0.36b	1.00 ± 0.22b	0.83 ± 0.40b	1.00 ± 0.45b	2.21 ± 0.14b
III	20	1.00 ± 0.00a	2.00 ± 0.00a	2.00 ± 0.00a	2.00 ± 0.00b	2.80 ± 0.08b	1.92 ± 0.08b	2.83 ± 0.17c	2.25 ± 0.17c	2.00 ± 0.22c	1.33 ± 0.42b	0.55 ± 0.22b	0.33 ± 0.21b	0.67 ± 0.42b	2.07 ± 0.15b
L.S.D (0.05)		0.00	0.00	0.00	0.00	0.145	0.145	0.415	0.490	0.415	0.975	0.580	0.789	1.08	0.145

Table 3 Mean number of frames covered with bees in honey bee colonies in three different groups from March, 2009 to March, 2010 (Mean ± S.E).

Group	n	Frames covered with adult bees from March, 2009 to March, 2010													Mean ± S.E
		March	April	May	June	July	August	September	October	November	December	January	February	March	
I	20	4.00 ± 0.00a	3.83 ± 0.11a	4,83 ± 0.11b	5.33 ± 0.17a	6.38 ± 0.08a	7.08 ± 0.08a	8.00 ± 0.00a	9.75 ± 0.17a	9.42 ± 0.20a	7.08 ± 0.27a	6.08 ± 0.08a	6.17 ± 0.11a	6.42 ± 0.20a	6.39 ± 0.13a
II	20	4.00 ± 0.00a	3.75 ± 0.20a	4.00 ± 0.00c	4.17 ± 0.11b	5.00 ± 0.00c	5.67 ± 0.17c	6.00 ± 0.00b	6.83 ± 0.11b	6.33 ± 0.21b	4.17 ± 0.83b	4.00 ± 0.81b	2.50 ± 1.12b	2.58 ± 1.16b	4.44 ± 0.36b
III	20	4.50 ± 0.00a	4.00 ± 0.00a	5.08 ± 0.08a	5.67 ± 0.17a	6.00 ± 0.00b	6.08 ± 0.08b	6.25 ± 0.17b	6.67 ± 0.17b	6.67 ± 0.21b	3.17 ± 1.01b	1.83 ± 0.83c	1.17 ± 0.75b	1.33 ± 0.84b	4.38 ± 0.33b
L.S.D (0.05)		0.511	0.395	0.234	0.449	0.310	0.355	0.373	0.454	0.626	2.332	2.023	2.349	2.517	0.145

Table 4 Mean numbers of foraging workers entered their colonies and foragers entered their colonies loaded with pollen of *A.m. jementica* (indigenous bees) and *A.m. carnica* (Carniolan bees) three times/day during different inspection months (Mean ± S.E).

Month of inspection	n	Forgers entered their hives and foragers returned loaded with pollen grains at 6–7 am, 11–12 am and 4–5 pm					
		6–7 am		11–12 am		4–5 pm	
		All foragers entered their colonies	Foragers entered loaded with pollen	All foragers entered their colonies	Foragers entered loaded with pollen	All foragers entered their colonies	Foragers entered loaded with pollen
(A) Indigenous bees (A.m. jementica)							
February	6	273.50 ± 30.12a	59.75 ± 7.93a	134.00 ± 6.26a	20.75 ± 3.15a	138.00 ± 9.05a	20.25 ± 3.97a
April	6	92.00 ± 6.92a	15.50 ± 1.85a	76.25 ± 10.69a	6.50 ± 1.19a	57.00 ± 3.16a	7.25 ± 0.75a
June	6	75.20 ± 8.80a	12.75 ± 1.80a	59.75 ± 9.91a	4.75 ± 0.85a	49.75 ± 2.69a	10.00 ± 1.68a
August	6	66.25 ± 3.73a	9.75 ± 1.38a	41.5 ± 5.14a	4.25 ± 0.75a	61.50 ± 6.20b	8.00 ± 0.58a
October	6	27.00 ± 2.80a	10.25 ± 1.11a	13.25 ± 1.11a	3.00 ± 0.41a	17.00 ± 2.12a	5.25 ± 0.63a
December	6	17.00 ± 2.48a	1.50 ± 0.65a	20.50 ± 2.22a	2.25 ± 0.25a	9.25 ± 0.63a	0.75 ± 0.25a
(B) Carniolan bees (A.m. carnica)							
February	6	204.00 ± 18.60a	63.00 ± 2.97a	137.75 ± 5.89a	19.75 ± 3.35a	134.00 ± 9.63a	11.50 ± 0.65a
April	6	80.25 ± 5.57a	9.75 ± 1.65a	63.50 ± 7.31a	5.75 ± 0.85a	52.00 ± 4.65a	5.75 ± 0.85a
June	6	72.25 ± 8.30a	5.75 ± 0.85b	55.50 ± 9.94a	1.00 ± 0.41b	38.50 ± 2.84b	5.00 ± 0.04b
August	6	56.25 ± 2.93a	2.75 ± 0.48ab	14.25 ± 3.57b	0.25 ± 0.25b	50.00 ± 9.63b	2.75 ± 0.48b
October	6	22.50 ± 0.96a	4.50 ± 0.65b	4.75 ± 0.85b	0.00 ± 0.00b	10.00 ± 1.08b	3.25 ± 0.63a
December	6	9.50 ± 0.65b	0.75 ± 0.25a	18.75 ± 0.85a	1.50 ± 0.29a	8.25 ± 1.31a	0.50 ± 0.29a

groups in March (F = 0.00, df = 59, P = 0.00) and April (F = 5.27, df = 59, P = 0.0185). In May honey bee colonies in group (III) had significantly more frames of bees, followed by group (I), meanwhile group (II) had significant less number of frames of bees (F = 53.46, df = 59, P = < 0.0001). During June, honey bee colonies in groups (I and III) had significantly more frames of bees, without significant difference between them. Meanwhile, honey bee colonies in group (II) had significantly less numbers of frames of bees (F = 27.92, df = 59, P = < 0.0001). Honey bee colonies in group (I) had significantly more frames of bees, followed by group (III). Meanwhile, honey bee colonies in group (II) had significantly less numbers of frames of bees during July (F = 38.17, df = 59, P = < 0.0001), and August (F = 38.17, df = 59, P = < 0.0001). During autumn season, honey bee colonies in group (I) had significantly more frames of bees, followed by groups (II and III), without significant difference between the last two groups, in September (F = 77.73, df = 59, P = < 0.0001), October (F = 132.55, df = 59, P = < 0.0001), and November (F = 66.51, df = 59, P = < 0.0001). In December, the same trend was obtained (F = 6.92, df = 59, P = 0.0074). In January honey bee colonies in group (I) had significantly more frames of bees, followed by group (II), meanwhile group (III) had significantly less number of frames of bees (F = 10.03, df = 59, P = 0.0017). During February group (I) had significantly more frames of bees, followed by group (II and III), without significant difference between the last two groups (F = 11.04, df = 59, P = 0.0011). In March, 2010 the same trend was obtained honey bee colonies in group (I) had significantly more frames of bees, followed by group (II and III), without significant difference between the last two groups (F = 10.06, df = 59, P = 0.0017) (Table 3).

General mean of frames covered with bees showed that honey bee colonies in group (I) significantly surpassed honey bee colonies in groups (II and III) in number of frames covered with bees (6.39, 4.44 and 4.38 comb/colony) in groups (I, II and III), respectively without significant difference between the last two groups (Table 3).

Foraging activity

The mean number of foraging workers entered to their colonies and those entered loaded with pollen grains in different inspection months are summarized in Table 4. The data showed that there is no significant difference in foraging activity between the two examined races (indigenous and carniolan bees) during the first inspection period of foraging which was extended from 6 to 7 am in all the inspection months. During the second inspection period which was extended from 11 to 12 am no significant difference in foraging activity for collecting pollen between the two races during February (F = 0.05, df = 5, P = 0.835) and April (F = 0.26, df = 5, P = 0.6269). In summer season when the air temperature gets very high the mean numbers of honey bee workers entered their colonies loaded with pollen was significantly higher in indigenous race than carniolan race during June (F = 15.70, df = 5, P = 0.0074) and August (F = 25.60, df = 5, P = 0.0023). The same trend was obtained during autumn season in October the numbers of honey bee workers entered their colonies loaded with pollen were significantly higher in indigenous race (F = 54.00, df = 59, P = 0.0003). During winter season in December no significant difference in foraging activity between the two examined races (F = 3.86,

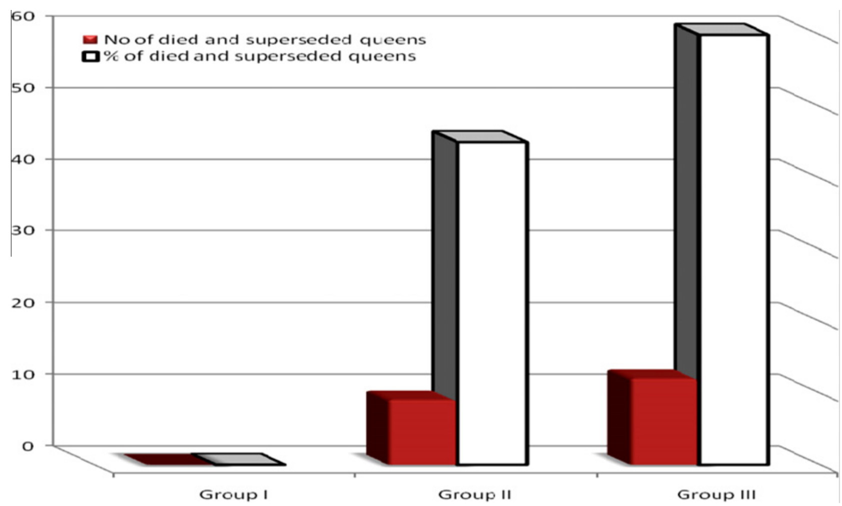

Fig. 1 Numbers and percentages of died and superseded queens in the experimental honeybee colonies for three different groups during experiment period extended from March, 2009 to March, 2010.

df = 5, P = 0.0972). During the third inspection period which was extended from 4 to 5 pm the same trend during the second inspection period was obtained, where no significant difference in foraging activity between the two races during February (F = 4.74, df = 5, P = 0.0723) and April (F = 1.74, df = 5, P = 0.235). Data also showed that in summer season, the mean numbers of honey bee workers entered their colonies loaded with pollen were significantly higher in indigenous race than carniolan race during June (F = 8.33, df = 5, P = 0.0278) and August (F = 49.60, df = 59, P = 0.0004). Meanwhile, no significant difference in foraging activity between the two examined races during October (F = 5.50, df = 5, P = 0.656) and December (F = 0.43, df = 5, P = 0.537) (Table 4).

Queen status

The numbers and percentages of died or superseded queens in three inspection groups (I, II and III) are presented in Fig. 1. Data showed that no died or superseded queens were found in honey bee colonies in group (1) during the experiment period which was extended from March, 2009 to March, 2010. Data also showed that, from March, 2009 to November, 2009 no died or superseded queens were found in honey bee colonies in groups (II and III). In December, 2009 three queens in group (II) and six queens in group (III) were superseded, represented (15% and 30%) for groups (II and III), respectively. In January, 2010 three queens in group (III) were superseded, represented (15%). In February, 2010 six queens in group (II) and three queens in group (III) were superseded, represented (30% and 15%) for groups (II and III), respectively. The numbers and percentages of queen failures during the experimental period were (0, 9 and 12), represented (0.0%, 45.0% and 60.0%) in groups (I, II and III), respectively (Fig. 1).

Discussion

Central region of Saudi Arabia has very high temperature often exceeds 45 °C and dry weather during summer season, under these conditions numerous imported honeybee colonies cannot survive. On the other hand, many beekeepers in Saudi Arabia have noticed that indigenous race (*A.m. jementica*) is more tolerant to environmental conditions than imported races (European races) (*A.m. carnica* and *A.m. logistica*), especially during summer season when air temperature gets very high. They also have noticed that during very high temperature in summer, indigenous race do not stop foraging for gathering pollen and nectar, but imported bees stop foraging. For the fore-mentioned reason the majority of them prefer to raise the indigenous race, and they prefer to raise them in traditional hives because raising this race in this type of hives by the time the characteristics of this race will change. Few scientific papers are done in this matter under the inspection area. However, to evaluate indigenous race and carniolan race in brood production, population development and foraging activity under central region of Saudi Arabia and to prove that if the cell size affects the productivity of indigenous queens, the current study was conducted. The obtained data revealed that, indigenous bees which are transferred from traditional hives (Aoud) into Langstroth (modern) hives were supplied with frames contained 33 worker-size cells/μ^2 (group I) had significantly higher brood production and population development than indigenous bees that transferred from traditional hives into Langstroth hives and supplied with frames contained 25 worker-size cells/μ^2 (group II), and carniolan bee which transferred from nuclei into Langstroth hives and supplied with combs contained 25 worker-size cells/μ^2 (group III). The general mean brood area in cm^2, frames of brood and frames covered with bees were (2813.13, 1730.94 and 1867.05 cm^2/colony), (3.13, 2.21 and 2.07 brood comb/colony) and (6.39, 4.44 and 4.38 comb of bees/colony), in groups I, II and III, respectively. These findings are in agreement with brood production and population development with the findings of (El-Sarrag,1993; Alqarni, 1995) who found that indigenous bees surpassed carniolan bees in brood production and pollen collection.

Foraging activity for honey bee races under the central region of Saudi Arabia environmental conditions takes place during day light; i.e. from sunrise until sun set during spring, autumn and winter if the nectar is available. Meanwhile, during the summer season, it takes place early in the morning and late of the day while air temperature gets lower and nectar secretion is available. The present data showed that no significant difference was found in foraging activity between the examined races for gathering pollen during the first inspection period extended from 6 to 7 am during the cold, moderate and very high air temperature in all the inspection months. This situation differed between the two examined races during the second and third inspection periods extended from 11 to 12 am and 4 to 5 pm, especially during the very high air temperature in June, August and October, where the indigenous race significantly surpassed these carniolan races in foraging activity for gathering pollen. These findings were found in agreement with data obtained by Gary (1967) and Woyke (1992) who found that flight activity significantly decreased with increasing air temperature. Alqarni (1995) found that the indigenous race surpassed the Carniolan and Italian bees in pollen collection. In addition, he also found that honey production was similar in the two races. Alqarni (2006) in Saudi Arabia found that the indigenous race (*A.m. jementica*) had significantly lower weight loss than the Carniolan and Italian races during summer season. Gary (1999) found that above 43 °C nectar and pollen foraging cease but water foraging was continued.

The current data also showed that foraging activity was significantly higher in the first inspection period (6–7 am) than the other two periods extended from 11 to 12 am and 4 to 5 pm, these findings agree with data obtained by Alqarni (2006) who found that foraging activity was significantly high at 8 am than 10 am. Abrol (2010) found that the foraging population correlated significantly and positively with air temperature, light intensity, solar radiation and nectar-sugar concentration and negatively with relative humidity. Meanwhile, data obtained by Silva and De Jang (1990) found that European bees had three foraging period, between 9 and 10 am, 11 and 12 am and 3 and 4 pm.

The numbers and percentages of died or superseded queens in three inspection groups I, II and III were studied, no died or superseded queens were found in honey bee colonies in group (I) during the experiment period. The percentages of queen failures during the experimental period were 0.0%, 45.0% and 60.0% in groups I, II and III, respectively.

From the fore-mentioned results, it could be concluded that, increasing the size of the cell negatively affected brood production and population density in indigenous race and indigenous race is more tolerant and well adapted to the environmental conditions in the search area than carniolan race (imported). Therefore, this study recommends that improving the characteristics of indigenous and carniolan race should take place through breeding programs, because the indigenous race shows high ability and well adaptation to the environmental conditions in the area but it is small in size, in addition their honey stomach and pollen basket are small, meanwhile the carniolan race is large in size and their honey stomach and pollen basket are great, but is not acclimatized to environmental conditions in the region, especially during the hot summer when the air temperature in the study region under exceeds 45 °C.

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