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Impact of temperature extremes on survival of indigenous and exotic honey bee subspecies, *Apis mellifera*, under desert and semiarid climates

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Abstract

Survival rates were monitored among three honey bee subspecies under two ecological regions within Saudi Arabia; Riyadh characterized by desert climate and Albaha resembling semiarid climate. Frequency of colony losses were counted and categorized within three temperature ranges of maximum monthly temperatures (20-28, 29-37 and 38-46 °C) for 24 months. Out of 420 colonies included in this study, 101 colonies were able to survive during the whole period of assessment. Survival rates among subspecies were highly associated with temperature ranges ($\chi^2 = 40.6$, df = 4, $P < 0.001$) and were significantly different between both ecological regions ($\chi^2 = 10.6$, df = 2, $P < 0.005$). Most of these losses (76%) occurred in summer months, August and September, when average maximum monthly temperature ranges between 38-46 °C. The highest losses were recorded in exotic honey bee subspecies; *Apis mellifera carnica* (92%) and *Apis mellifera ligustica* (84%), compared to (46%) in the local honey bee colonies, *Apis mellifera jemenitica*. Apparently extreme ambient temperatures during the summer season are highly detrimental to exotic honey bee colonies. Additionally, *Varroa* mite and *Nosema* spp. were the main pests that can contribute to colony losses throughout the period of the study. Results indicate low tolerance of the exotic honey bee subspecies to temperatures extremes of Saudi Arabia during the summer, thus selection and conservation of the indigenous honey bee race is highly demanded.

Key words: survival frequency, drought, Yemeni honey bee, Italian honey bee, Carniolan honey bee.

Introduction

To understand annual survival rates or losses in honey bee colonies, *Apis mellifera* L., under hot and dry regions, the ecosystem impact on the indigenous and exotic subspecies should be highly focused. Ecological limitations such as drought, severe ambient summer temperatures, *Varroa* mite infestation levels, improper use of pesticides, and inadequate management practices comprise the most obvious influences on beekeeping in this region (Alattal *et al*., 2014b; Alghamdi *et al*., 2013; Alqarni *et al*., 2011; Ali, 2011). In summer months, average maximum temperature exceeds 40 °C in most of Saudi Arabia (PoMEP, 2014). A recent study reported significant decrease in precipitation (47 mm/decade) and significant increase in maximum average temperature (0.71 °C/decade) which may reform agricultural activities including beekeeping within the country (Almazroui *et al*., 2012). Saudi beekeepers depend on importations of exotic honey bee packages to construct their colonies, which may explain the increasing demand and the limited availability of local honey bee colonies prior to the flow season (MoEP, 2012). However, growing importations of exotic honey bee subspecies may bear significant risk on the conservation of the indigenous honey bee (Alattal *et al*., 2014b). Indeed, beekeepers are confined to unique beekeeping practices and suffer from relatively very low colony productivity and high annual losses (Alqarni *et al*., 2011; Alghamdi and Nuru, 2013). Apiaries management scheme focuses primarily on honey production with minimal procedures to prevent summer or winter colony losses, which seems economically unfeasible and exhaustive. Yet, variations in the honey bee body characteristics and colony performance among exotic honey bee subspecies such as Italian (*Apis mellifera ligustica* Spinola) and Carniolan (*Apis mellifera carnica* Pollmann) compared with the indigenous honey bee subspecies, *Apis mellifera jemenitica* Ruttner, were documented (Ali, 2011; Alqarni *et al*., 2011; Alghamdi *et al*., 2013; Alqarni *et al*., 2013; Alattal *et al*., 2014a; 2014c). Saudi Arabia provide ideal place to investigate the impact of extreme temperatures on European honey bee races compared with the indigenous honey bee race, which is the smallest and the most heat tolerant honey bee subspecies (Ruttner, 1988; Alattal *et al*., 2014a). Preliminary reports provided some data that may indicate lower heat tolerance, shorter foraging durations and higher *Varroa* mite infestation rates in exotic honey bee subspecies compared to the indigenous honey bee *A. m. jemenitica*, (Alghamdi, 2002; Abou-Shaara *et al.*, 2012; Alqarni *et al*., 2014). Additionally, comparisons based on field surveys confirmed higher survival rates in the indigenous honey bee compared to exotic subspecies under Saudi Arabia conditions (Ali, 2011; Abou-Shaara *et al.*, 2012). As these comparisons were based on sporadic and short observations in which beekeepers enclose either exotic or indigenous honey bee subspecies or have different management schemes for both subspecies, in this study we will monitor long term survival rates among two exotic honey bee subspecies compared with the indigenous honey bee under desert and semiarid ecosystems of Saudi Arabia.

Materials and methods

To construct colonies of exotic honey bee subspecies *A. m. ligustica* and *A. m. carnica*, queenless colonies were headed with young imported queens (140 queens from each subspecies) obtained from certified Australian producers (New South Wales, Australia), while indigenous honey bee colonies, *A. m. jemenitica*, were obtained from local beekeepers (Jazan, Saudi Arabia). Subspecies loyalty was confirmed by morphometric means (Ruttner, 1988). After colony standardization, all colonies were treated once against *Varroa* mite using fluvalinate. Each colony consisted of 3-4 brood frames and 7-8 adult bee frames. Finally, colonies from each subspecies were distributed randomly and equally between two distinctive ecological regions in Saudi Arabia; Riyadh (24°43'19.2"N 46°37'37.2"E, that comprises a desert ecosystem, and Al-Baha (19°51'34"N 41°33'26"E) that comprises a semi arid ecosystem. Based on monthly climatic data, three thermal classes for maximum monthly temperatures were assigned. The first temperature class (20-28 °C) includes the months from December to March, the second class (29-37 °C) includes April, October and November and the last class (37-46 °C) includes the months from May to September. Numbers of colony losses were recorded monthly at both locations for all three honey bee subspecies for twenty four months, and frequency of colony losses in each month was assigned to one of the three thermal classes. During the observation period and based on symptoms, incidence of *Varroa* mite, *Nosema*, American foulbrood, European foulbrood and chalkbrood were recorded each month in all survived colonies. Colonies that show infection by *Nosema*, without distinguishing between *N. apis* and *N. ceranae*, and European foulbrood were treated once using proper control agent.

Results

Out of 420 colonies included in this study, 101 colonies were able to survive until the end of the monitoring period. Survival rates among subspecies were highly associated with temperature classes (χ^2 = 40.6, df = 4, P < 0.001) (figure 1) and were significantly different between both ecological regions (χ^2 = 10.6, df = 2, P < 0.005) (figure 2). Most of these losses (76%, N = 320) occurred in summer months, August and September, at the highest thermal class of the year 38-46 °C (figure 1). The highest losses were recorded in European honey bee subspecies, Carniolan colonies (92%) and Italian colonies (84%), with higher variation among thermal classes compared to the indigenous honey bee subspecies (46%) (figure 3).

In Riyadh, a desert ecosystem, association of survival rates with thermal ranges was highly significant (χ^2 = 35.6, df = 4, P < 0.005). Losses in the local honey bee race were almost the same in the first and second year; however most of the Carniolan colonies (81%) and more than half of the Italian colonies (59%) were lost in the first year (figure 1). At the end of the assessment, none of the Carniolan colonies, 8 Italian colonies and 33 local colonies survived in Riyadh. Survival rates in Albaha, a semiarid ecosystem, were relatively higher in exotic honey bee races compared to Riyadh, desert ecosystem (figure 2). However the situation in Albaha is still very similar to that of Riyadh. Survival rates were highly associated with thermal classes (χ^2 = 37.3, df = 4, P < 0.005). Losses in the local honey bee race were almost the same in the first and second year and most of the Carniolan colonies (59%) and Italian colonies (49%) died in the first year. At the end of the assessment, 11 Carniolan colonies, 15 Italian colonies and 34 indigenous colonies survived.

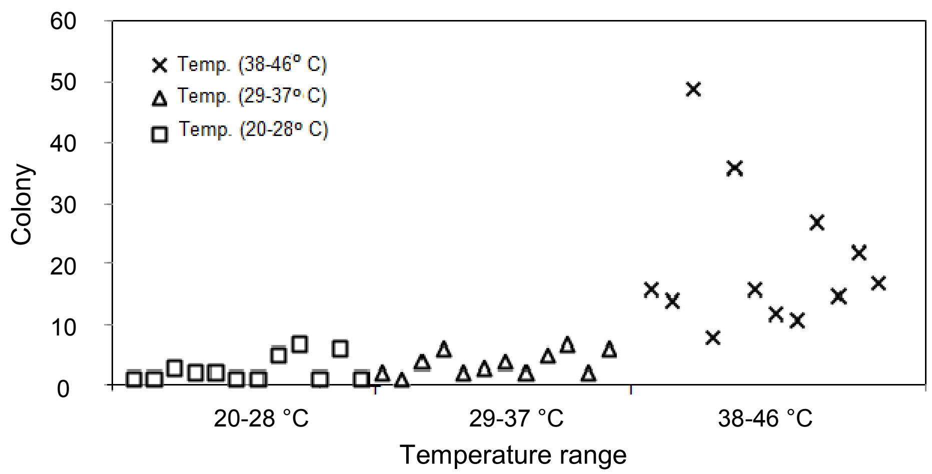

Figure 1. Frequency of honey bee colony losses within the three thermal classes (20-28, 29-37 and 38-46 °C). In each class the number of lost colonies of each honey bee subspecies in each region were recorded for two successive years (N = 12). Colony losses are highly associated with different temperature ranges (χ^2 = 40.6, df = 4, P < 0.001).

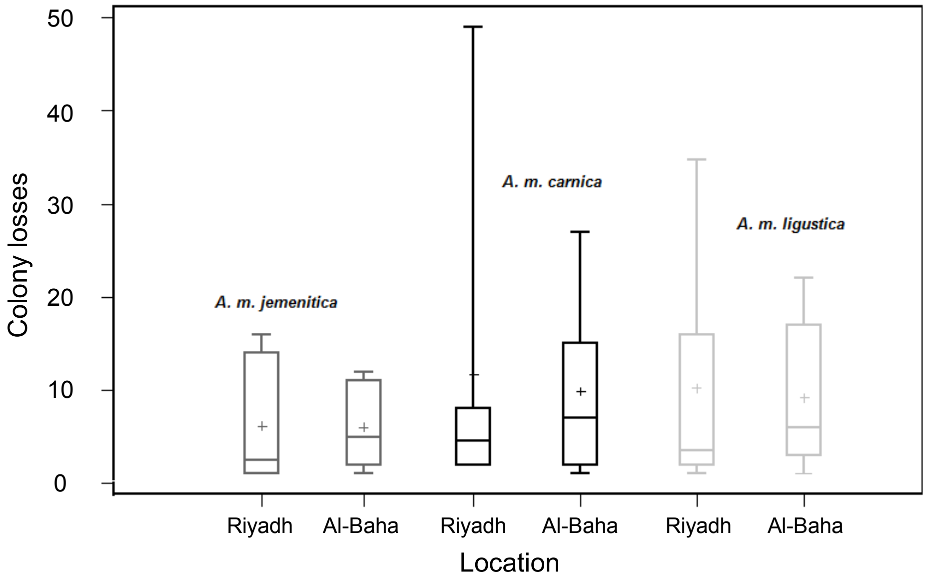

Figure 2. Colony losses of the Yemeni, Italian and Carniolan honey bee subspecies in Riyadh (desert climate) and Al-Baha (semiarid climate), recorded within three thermal classes (20-28, 29-37 and 38-46 °C) from March 2012 to March 2014. Results indicated significant variation between both locations ($\chi^2 = 10.6$, df = 2, $P < 0.005$).

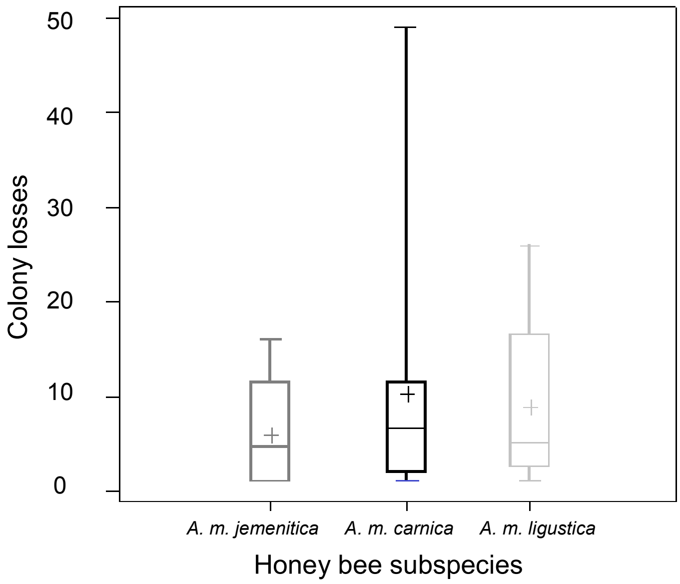

Figure 3. Colony losses within investigated honey bee subspecies: *A. m. jemenitica*, *A. m. carnica* and *A. m. ligustica*, recorded within three thermal classes (20-28, 29-37 and 38-46 °C) of maximum average monthly temperatures for two successive years in two locations: Riyadh (desert climate) and Al-Baha (semiarid climate). Results showed strong association between colony losses and maximum monthly recorded temperatures ($\chi^2 = 40.6$, df = 4, $P < 0.001$) with higher survival rates of the indigenous honey bee subspecies compared with exotic.

Table 1. Number of exotic and indigenous honey bee colonies infested with *Varroa* mite or showing disease symptoms in both locations.

Pests	Riyadh			Al-Baha		
	A. m. jemenitica	*A. m. carnica*	*A. m. liguistica*	*A. m. jemenitica*	*A. m. carnica*	*A. m. liguistica*
Varroa	62	70	70	62	69	70
Nosema	4	11	9	7	18	15
Chalkbrood	0	7	9	1	11	13
AFB	0	0	0	0	0	0
EFB	0	0	0	0	3	2

Presence of disease agents and parasites was monitored during the study. Results indicate that *Varroa* mite is frequently infesting honey bee colonies throughout the year with most colonies were infested. Presence of *Nosema* was recorded in 46 colonies (≈ 11%) and 3 colonies (< 1%) were infected with European foulbrood while non were infected with American foulbrood (table 1).

Discussion and conclusion

Saudi Arabia provide ideal place to investigate the impact of temperature extremes on heat adapted or less adapted honey bee subspecies. Although we haven't any report to document average annual colony losses in Saudi Arabia or its causes, it should be considered that such losses are increasing and are highly associated with importation of exotic honey bee subspecies. Regardless of the differences in colony losses among exotic honey bee subspecies compared with indigenous honey bee subspecies, the majority of these losses occurred during summer months, August and September, indicating a limited tolerance to extreme ambient temperatures in exotic honey bee subspecies. This demonstrates that heat tolerance is the unique additional criterion for successful and sustainable beekeeping in the country compared with many other location of the world, and importation of exotic honey bee subspecies should be reconsidered. None or less adapted honey bee subspecies will suffer significantly during summer and may not be able to survive over summer seasons. The physiological and behavior activities of colony thermoregulation and survival strategies of the European subspecies may be different than those of the indigenous honey bee of Saudi Arabia; consequently losses will certainly increase as importations of exotic honey bee subspecies increased. Although, survival rates were significantly higher in Albaba region with milder temperatures and higher precipitations, losses were still intolerable and unaffordable. If Saudi Arabia has milder climatic region than Albaha, then colonies should be moved to these regions to silence the effect of extreme temperatures.

The incidence of *Varroa* mite infestation and other disease agents may contribute crucially to colony losses and entails an adequate and effective control measures that should be adopted in time to prevent losses. Novel diagnostic and selection methods of tolerant honey bee stocks should be employed to sustain beekeeping in this region. Furthermore, management of colonies under extreme temperature in summer should be focused as well. We conclude that the indigenous honey bee subspecies can withstand extreme temperature conditions compared with exotic subspecies but it cannot withstand other disease factors such as *Varroa* and *Nosema* infestation.

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