http://dx.doi.org/10.22319/rmcp.v10i1.4387

Technical note

Populations and food stores of honey bee (*Apis mellifera*) colonies from three regions of Mexico's semiarid high plateau

Carlos Aurelio Medina-Flores[a*]

Ernesto Guzmán-Novoa[b]

Jairo Iván Aguilera Soto[a]

Marco Antonio López Carlos[a]

Sergio Ernesto Medina-Cuéllar[c]

[a] Universidad Autónoma de Zacatecas. Unidad Académica de Medicina Veterinaria y Zootecnia, Carretera Panamericana Zacatecas-Fresnillo km 31.5, El Cordovel, Enrique Estrada. CP. 98500, Zacatecas, México.

[b] University of Guelph. School of Environmental Sciences. Guelph, ON, N1G 2W1, Canada.

[c] Universidad de Guanajuato. Campus Irapuato-Salamanca, Departamento de Arte y Empresa, Salamanca, Guanajuato, México.

*Corresponding author: carlosmedina@uaz.edu.mx

Abstract:

The aim of this study was to determine the number of adult bees, brood areas, honey and pollen from 150 honey bee (*Apis mellifera*) colonies in spring and fall in the temperate semidry, temperate sub-humid and semi-warm semi-dry regions of Zacatecas, Mexico. The colonies in the semi-warm semi-dry region had significantly more bees and brood in the fall than those in the other regions (P=0.001). In the spring, colony populations in the temperate semi-dry and semi-warm semi-dry regions were similar and significantly greater than those in the temperate sub-humid region (P<0.01). There was significantly less honey and more pollen stored in the fall, in hives of the semi-warm semi-dry region than in hives of the other regions (P=0.001). In the spring, the area of stored pollen in colonies of the temperate semidry region was significantly greater than that of colonies from the other regions (P<0.0001). The population of adult bees and brood areas of colonies in the fall correlated positively with bee population, brood and honey areas in the spring (P<0.001). In the fall, the semi-warm semi-dry region had better conditions for developing and reproducing colonies than the other regions. However, the population sizes of the colonies studied (21,000 to 35,000 bees/hive) are not considered optimal (>50,000), and thus, it is suggested that previous to blossom seasons, strategies aimed at increasing bee population and food stores, that contribute to winter colony survival and to improve their productivity, are implemented.

Key words: *Apis mellifera*, Bee population, Brood areas, Honey, Pollen, Climatic regions.

Received: 25/02/2017

Accepted: 11/02/2018

The state of Zacatecas occupies the tenth place as honey producer in Mexico, and the first in the northern region of the country, with an annual yield of 1,603 t[1]. Honey production and the survival of honey bee (*Apis mellifera*) colonies depend on the effect and interaction of various factors, namely the population size of the colonies, the industriousness of the bees and the environment[2]. However, for the state of Zacatecas, and generally for the semiarid high plateau of Mexico, the environmental conditions demand efficient management processes to contribute to the optimal exploitation of floral resources.

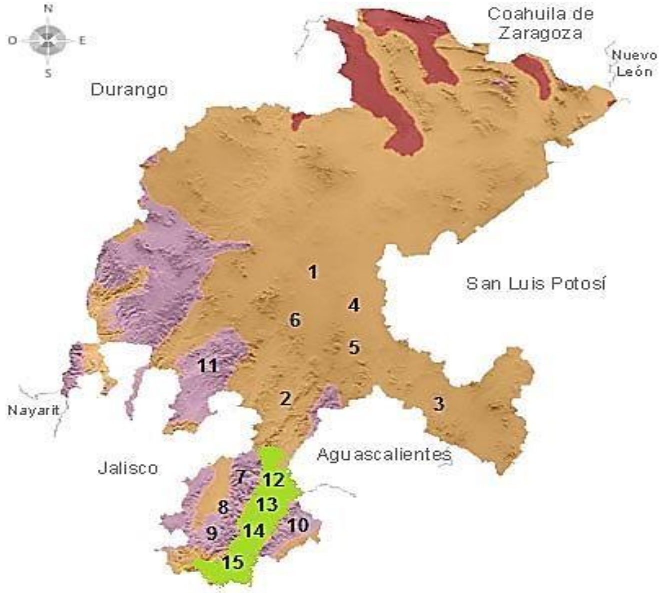
Regarding the above stated, the growth of honey bee colonies under natural conditions is related to the availability of pollen and nectar in the field. The entry of nectar and pollen into the hive stimulates the egg laying rate of the queen, which results in an increase of the colony's population[3]. Honey production in honey bee colonies is associated to a rapid exploitation of the blossom season by the bees; therefore, the blooming period must coincide with the existence of an abundant bee population in the hive for the attainment of a higher honey yield. The colony must produce an abundant amount of brood before the blossom season, so that the maximum population may coincide with the nectar flow[2]. In addition to honey production, population and nutritional parameters are important indicators of the survival of honey bee colonies during the winter[4], which has both economic and ecological implications.

Because of the above, it is of interest for researchers and beekeepers to know the size of the population and food reserves of honey bee colonies at different times of the year and in different climatic regions. This knowledge may allow producers to implement management strategies during the pre-harvest season that may contribute to increase honey yields as well as to reduce the rate of colony losses during critical seasons (e.g. winter), and the execution of these management strategies will depend on the natural development of bee populations in each region.

The objective of this study was to determine the population size and food stores of honey bee colonies during the two main blossom seasons in the three climatic regions of more apicultural importance for the state of Zacatecas.

To achieve this goal, the population size and food stores in 20 % of the commercial bee colonies located in 25 apiaries of three climatic regions of the state of Zacatecas were assessed. These evaluations were carried out on two occasions: during mid-autumn, 2010 (n= 150 colonies), and during mid-spring, 2011 (n= 150 colonies). Ninety (90) % of the colonies sampled in the fall were also sampled in the spring; the remaining 10 % were different, as 15 were lost during the winter. The colonies studied were selected at random from each sampled apiary, as long as they were visually perceived as clinically healthy. The colonies belonged to different producers; therefore, the management, origin and age of the queens were heterogeneous, a condition shared by the three regions studied. It was assumed that, as a whole and due to the large number of repetitions, the average management conditions in the state were adequately represented. The value of this work lies in that it makes relative comparisons of the conditions of honey bee colonies between regions. The colonies were distributed in 15 municipalities that belong to the three ecological regions with the greatest apicutural importance for the state of Zacatecas, Mexico (22° 57' N, 102° 42' W) (Figure 1). In each region, 50 colonies were analyzed in the fall, and 50 in the spring, and so were 8 to 13 colonies in each municipality. The main characteristics of each region in terms of climate and vegetation are described below.

Figure 1: Map of Zacatecas showing the location of the colonies analyzed in the various regions



Semi-dry temperate: Fresnillo (1), Villanueva (2), Villa García (3), Guadalupe (4), Ojo Caliente, (5) and Zacatecas (6).
Sub-humid temperate: Tepechitlán (7), Tlantenango (8), Momax (9), Nochistlán (10), and Valparaíso (11).
Semi-dry semi-warm: Tabasco (12), Jalpa (13), Juchipila (14), and Moyahua (15).

Semi-dry temperate Region (SDT). It covers 60 % of the surface area of the state's territory and is the most arid, high, cold and dry of the three regions studied. Its mean annual precipitation, temperature and relative humidity are 469 mm, 15 °C and 54 %, respectively. This region has less diversity of plant species than the other regions of the state, and the dominant vegetation type is the medium-sized open grassland(5). Two important nectar flows occur every year, one in the spring (mainly from mesquite (*Prosopis laevigata*)), and another in the fall. The latter is the most important for apiculture in the state and is a product of the blossoming of various shrubs, such as *aceitilla* or Spanish needle (*Bidens odorata*), *lampote* or Mexican sunflower (*Tithonia tubaeformis*) and *lampotillo* or bushsunflower (*Simsia amplexicaulis*)(5-7). The colonies of this region were located in nine apiaries of the municipalities of Fresnillo, Villanueva, Villa García, Guadalupe, Ojo Caliente and Zacatecas, at altitudes of 1,800 to 2,400 m asl.

Sub-humid temperate region (SHT). The mean annual precipitation, temperature and relative humidity parameters of this region are 680 mm, 18 °C and 66.7 %, respectively. The climate of the region constitutes a transition between the SDT and SDSW regions. The vegetation is deciduous sclerophyllous broadleaved(5), and the flora with apicultural importance during the spring consists of *tepame* or feather acacia (*Acacia pennatula*) and pointleaf manzanita (*Arctostaphylos pungens*), and at the end of the summer and in the fall, of catclaw mimosa (*Mimosa aculeaticarpa*), pointleaf manzanita (*Arctostaphylos pungens*), and kidneywood trees (*Eysenhardtia polystachya*)(5-7). The colonies in this region were located in eight apiaries in the municipalities of Tepechitlán, Tlantenango, Momax, Nochistlán, and Valparaíso, at altitudes of 1,200 to 2,000 m asl.

Semi-dry semi-warm region (SDSW). The annual mean precipitation, temperature and relative humidity of this region are 704 mm, 19.5 °C and 55 %, respectively(5). It is the lowest, warmest and most humid of the three studied regions; besides, it contains a greater diversity of floral resources than the other two regions. This region exhibits two main nectar flows of herbs, trees, and deciduous shrubs. In the spring, mesquite (*Prosopis laevigata*) is the main plant of apicultural interest, whereas several species produce nectar or pollen in the fall, such as crownbeard (*Verbesina platyptera*), *venadilla* or torchwood copal (*Bursera fagaroides*), and *ochote* or casahuate (*Ipomoea murucoides*)(5-7). The colonies studied were located in eight apiaries of the municipalities of de Tabasco, Jalpa, Juchipila and Moyahua, at altitudes of between 1,000 and 1,400 m asl.

The bee population of the colonies was estimated by counting the number of combs covered by bees, and multiplying them by the number of bees that occupy a jumbo-size brood frame on both sides (3,960 bees), as established for Africanized bees by Delaplane *et al*(8). The brood areas and food stores were estimated based on the mean percentage estimated by two operators of the surface of each side of the comb occupied by capped brood, honey, and pollen. This percent surface area was then converted to area (cm^2), using as a base, the surface of a jumbo frame on both sides (2,260 cm^2)(8,9). The measurements were made during the afternoon-evening period (1600 to 1900 h), when most bees were inside the hives.

The data obtained for the number of bees and the comb area occupied by brood, honey, and pollen were square root-arcsine transformed to normalize their distribution(10). The two seasons of the year were compared, subjecting the data for the studied variables to Student *t* tests. To determine whether there were differences between the regions for the variables studied, the transformed data were subjected to analyses of variance (ANOVA), and when significant differences were detected, the means were compared using a Tukey test. Pearson's correlation analysis was also used to determine the relationship between the registered variables(11).

Considering all regions, the results show significantly larger bee populations, brood and honey areas in the spring than in the fall, whereas the pollen areas were significantly larger during the fall (Table 1).

Table 1: Values (mean ± SE) for the number of bees and comb areas with brood, honey and pollen in honey bee colonies during the spring and fall

Variable	Fall	Spring	*t* and *P*
Bees per colony	23,550±626	33,044±539	56.9 <.0001
Brood areas, cm^2	9,392±362	10,168±288	41.9 <.0001
Honey areas, cm^2	6,443±338	7,177±289	30.4 <.0001
Pollen areas, cm^2	1,975±161	1,328±136	15.4 <.0001

Likewise, considering both seasons, the results show that the colonies located in the SDSW region had larger bee populations and brood areas than the colonies in the two other regions. The honey reserve areas of the colonies in the SDT and SHT regions were larger than in the colonies of the SDSW region. The pollen areas were smaller in the SHT region than in the SDT and SDSW regions and there were no significant differences between them (Table 2).

Table 2: Values (mean ± SE) for the number of bees and comb areas with brood, honey and pollen in honey bee colonies in three regions of the state of Zacatecas

Variable	Semi-dry temperate	Sub-humid temperate	Semi-dry semiwarm	F and *P*
Bees per colony	27,960±981^{a,b}	26,800±876^{b}	29,954±678^{a}	3.52 0.030
Brood areas, cm^2	9,245±448^{b}	9,186±375^{b}	10,874±363^{a}	5.8 0.0032
Honey areas, cm^2	7,647±304^{a}	7,407±409^{a}	5,392±399^{b}	10.9 <.0001
Pollen areas, cm^2	2,145±206^{a}	1,130±124^{b}	1,689±202^{a}	7.7 0.0005

^{ab} Different letters in the same row indicate significant differences based on analyses of variance and Tukey tests.

Table 3 shows the mean values for bee populations per colony and brood area for the three regions and the two seasons of the year; the colonies of the SDSW region had a larger bee population during the fall than those of the SDT and SHT regions, between which there were no significant differences for that season. In the spring, the colonies of the SDT and SDSW regions had a similar bee population, which was significantly larger than that of the colonies located in the SHT region.

Table 3: Values (mean ± SE) for the number of bees and comb areas with brood in honey bee colonies of three regions during the spring and fall

Region	No. of bees per colony in the fall	No. of bees per colony in the spring	t and P	Brood areas (cm^2) in the fall	Brood areas (cm^2) in the spring	t and *P*
Semi-dry temperate	20,908±1,091[b]	35,155±779[a]	t=112.8 *P*=0.0001	6,282±461[c]	12,268±489[a]	t=80.9 *P*=0.0001
Sub-humid temperate	22,888±1,200[b]	30,791±1,032[b]	t=51.2 *P*=0.0001	9,695±611[b]	8,666±439[b]	t=3.8 *P*=0.052
Semi-dry semiwarm	26,788±804[a]	33,185±913[a]	t=28.2 *P*=0.0001	12,141±526[a]	9,582±445[b]	t=14 *P*=0.0003
F and *P*	F=8.38 *P*=0.0004	F=5.79 *P*=0.003		F=30.72 *P*=0.0001	F=16.92 *P*=0.0001	

[ab] Different letters in the same column indicate significant differences. The *t* and associated probability values are the result of the comparison between the seasons of the year for each region.

In the fall, the brood areas were largest in the colonies of the SDSW region, while in the spring, the brood areas were significantly larger in the SDT region than in the other two regions (Table 3).

Table 4 shows that there was significantly less honey stored in the hives of the SDSW region during the fall than in the hives of other regions. The honey areas in the colonies of the three regions were not significantly different in the spring. In the fall, the pollen areas were largest in colonies of the SDSW region, while those of the SDT region were significantly larger than those of the colonies of the other regions.

Table 4: Mean values for comb areas with honey and pollen of three regions during spring and fall

Region	Honey areas (cm^2) in the fall	Honey areas (cm^2) in the spring	t and P	Pollen areas (cm^2) in the fall	Pollen areas (cm^2) in the spring	t and *P*
Semi-dry temperate	8,701±474[a]	6,572±320[a]	t=13.7 *P*=0.0003	1,943±304[b]	2,352±286[a]	t=.98 *P*=0.32
Sub-humid temperate	7,774±561[a]	7,033±609[a]	t=1,6 *P*=0.20	1,175±159[c]	1,083±196[b]	t=.27 *P*=0.60
Semi-dry semiwarm	2,924±351[b]	7,910±530[a]	t=62.9 *P*=0.0001	2,791±310[a]	565±139[b]	t=43.1 *P*=0.0001
F and *P*	F=44.55 *P*=0.0001	F=1.88 *P*=0.15		F=9.32 *P*=0.0002	F=18.64, *P*=0.0001	

[ab] Different letters in the same column indicate significant differences. The *t* and associated probability values are the result of the comparison between the seasons of the year.

A positive and significant correlation was found between the number of bees and the brood areas of the colonies in the two seasons of the year (fall: r= 0.79, P<0.001; spring: r= 0.54, P<0.001, n= 150). The bee population in the fall was positively and significantly correlated with the bee population and brood and honey areas registered in the spring (r= 0.32, r= 0.36, r= 0.28, respectively; n= 150, P<0.0001). Likewise, the brood area of the colonies in the fall showed a significant correlation with the bee population and brood and honey areas in the spring (r= 0.30, r= 0.33, r= 0.26, respectively; n= 150, P<0.001). No significant correlations were found in either season between the pollen areas and the bee population of the colonies.

These results show that the population conditions and honey stores were better in the spring than in the fall, and that the SDSW region had a larger bee population and brood areas than those of the SDT and SHT regions, both of which have lower temperatures, precipitations and diversity of plant species than the SDSW region(5).

Considering the three regions and the two seasons as a whole, the results show that the bee population size and the brood areas were largest in the fall for the colonies located in the SDSW region, and only in the spring were the brood areas largest in the SDT region. This may be due mainly to differences between the regions in terms of environmental conditions such as the diversity of plant species, precipitation, temperature and humidity. For example, the fact that the pollen stores (a source of protein) were relatively high in the fall and relatively low in the spring in the colonies of the SDSW region may account to some extent for the fact that the colonies of this region had significantly more brood and bees in the fall than those of the two other regions. There may be a higher availability of pollen from the plant species of the semi-dry semi-warm region (*Verbesina platyptera*, *Bursera fagaroides* and *Ipomoea murucoides*) than from the species of the semi-dry temperate region (*Bidens odorata*, *Tithonia tubaeformis* and *Simsia amplexicaulis*) and the sub-humid temperate region (*Mimosa aculeaticarpa*, *Arctostaphylos pungens* and *Eysenhardtia polystachya*).

Notably, the largest bee population and brood sizes in the fall for the colonies of the SDSW region did not result in a larger amount of stored honey. In this region, more honey and less pollen were found in the spring, and more pollen and less honey in the fall, than in the SDT and SHT regions, possibly because the intensity of the nectar flow from the flowers was insufficient to result in a high storage of food reserves, which also diminished due to a greater consumption of food by the increased bee population. Such large bee and brood population size may not have lasted long, since the reduction in the amount of food would reduce the egg laying rate of the queen and, therefore, in the bee population(12). Although a high honey production would not be expected, the production of bees and brood in the SDSW region during the fall is sufficient to use it for the production of honey bee nuclei, which have a high commercial value.

The brood area and bee populations depend on the food stores in the colony and on the availability of these in the field(13). If the stores and availability of pollen are low, there will be less protein with which to feed larvae, and therefore the quality (in terms of size, nutrition and viability) and quantity of bees in the next generation (35 d) may be reduced. This, in turn, has a negative impact on colony development [14,15]. This scenario agrees with the findings of this study in the sense that there was a significant relationship between the number of bees and brood area in the fall and in the spring.

The protein content of flowers' pollen in Mexico has not been studied; however, reports from other countries reveal wide variations between plant species (2 to 62 %)[16]. Because of this, when the colony does not have sufficient pollen, or when the protein content of the stored pollen is lower than 20 %, the colony tends to collect a larger amount of pollen to cover its nutritional requirements; otherwise, the egg laying rate of the queen will decrease[17], and this will lead to a less than optimal development of the colony. The different regions of the present study vary in diversity, distribution and abundance of plant species, and therefore, based on the amount of stored pollen, we may speculate that there may be a different contribution of nutritional elements in the pollen collected by the bees in the various regions, and the absence of correlation between the pollen reserve areas and the population size (brood and bees) of the colonies. However, this hypothesis must be proven in future studies.

The bee population and the food reserves of the colonies in the fall have been reported to influence the population size in the following spring[4]; this, in turn, can impact the bee populations in the summer and, therefore, the productivity of the colony. This coincides with the correlations found in the present study, which suggest that, if the bee population, the brood area and honey stores increase in mid-autumn, they will also increase in the spring. Furthermore, Guzmán-Novoa *et al*[4] found that a low population size and low food stores are associated, respectively, with 69 and 68 % of the colony mortality cases during winter.

Both seasons analyzed in this study, correspond to blossom periods and honey harvests in the semi-arid high plateau of Mexico. However, it was observed that, with the exception of the SDSW region, the best conditions for the development of colonies occurred in the spring, when bee populations and pollen stores in the colonies were larger.

The environmental conditions and the management of colonies are factors that vary and thus have a significant impact on the survival and population size of honey bee colonies, as well as on their honey production. In Zacatecas, the average yields of honey per hive range between 17.5 and 30 kg per blossom season[18,19]; however, it is highly probable that these yields could be improved. For this reason, it is indispensable that beekeepers monitor the sanitary, population, and nutritional status of their colonies at various times of the year, to implement management strategies previous to harvesting, such as requeening of colonies, disease control, use of nutritional supplements, and hive mobilization, (at least 45 d) before the nectar flow. This will allow time to achieve the maximum bee populations in the colonies to coincide with the beginning of the nectar flow.

The mean populations of approximately 21,000 to 35,000 bees per hive found in the blossom seasons in the present study were above those reported in *Apis mellifera syriaca* colonies of

Jordan, under semi-arid conditions of the Mediterranean[20], and similar to the mean populations of colonies under tropical conditions in the state of Chiapas, México[21], but inferior to those of colonies in Canada, where populations of over 50,000 bees per colony have been registered[2]. It may be inferred that the management previous to the honey harvest of the colonies studied herein might have not been adequate. This hypothesis is based on the fact that, unlike the regions of Chiapas and Canada, the blossom periods of the semi-arid high plateau of Mexico are generally sudden and short but occur with an abundant nectar flow, which demands that the beekeepers be more efficient in managing their colonies to be able to better exploit the floral resources available.

The low population size of colonies observed in this study is understandable, because most beekeepers in Mexico prefer not to feed their colonies before the blossom seasons, expecting that they will strengthen during the season (personal observation). As a result of this strategy, the mean yield per colony tends to be low, since the colonies reach their maximum populations at the end of the blossom season. Therefore, it would make sense to carry out studies to compare honey yields between colonies with alternate management strategies that include requeening and the administration of artificial feeding (energetic and protein), as well as disease and parasite control previous to the blossom seasons, since it is known that various pathologies can significantly affect the productivity and populations of honey bee colonies in the Mexican high plateau[19,22,23]. Such studies would allow making specific recommendations for increasing the honey production and survival of honey bee colonies in the winter.

It is concluded that, compared to other regions, the natural conditions of the semi-dry semiwarm region offer the best possibilities of development for honey bee colonies, particularly in the fall, which does not necessarily result in a larger amount of stored honey, but may translate into a larger amount of brood and bees for reproductive purposes meant to produce honey bee nuclei. It is also concluded that, in general, the size of the bee populations found in the colonies studied during two blossom seasons are not optimal for the production of honey, and thus, it is proposed that they may be increased with management practices validated by scientific studies.

Acknowledgements

The authors wish to thank Laura Espinosa, José Luis Uribe, Carlos Aréchiga, and Ramón Gutiérrez for their valuable contributions to a previous version of this manuscript.

Literature cited:

1. Secretaría de Agricultura, Ganadería, Desarrollo Rural, Pesca y Alimentación. (SAGARPA). Servicio de información estadística agroalimentaria y pesquera (SIAP). 2011. http://www.siap.sagarpa.gob.mx. Consultado Sep 18, 2017.

2. Szabo TI, Lefkovich LP. Effect of brood production and population size on honey production of honeybee colonies in Alberta, Canada. Apidologie 1989;20(2):157-163.

3. Fewell JH, Winston ML. Colony state and regulation of pollen foraging in the honey bee, *Apis mellifera* L. Behav Ecol Soc 1992;30(6):387-393.

4. Guzmán-Novoa E, Eccles L, Calvete Y, Mcgowan J, Kelly PG, Correa-Benítez A. *Varroa destructor* is the main culprit for the death and reduced populations of overwintered honey bee (*Apis mellifera*) colonies in Ontario, Canada. Apidologie 2010;41(4):443-450.

5. INEGI. Instituto Nacional de Estadística Geografía e Informática. Municipios de Zacatecas. 2005.

6. Acosta-Castellanos S, Quiroz-García L, Arreguín-Sánchez MDLL, Fernández-Nava R. Análisis polínico de tres muestras de miel de Zacatecas, México. Polibotánica 2011;(32):179-191.

7. Franco OVH, Siqueiros DME, Hernández AEG. Flora apícola del estado de Aguascalientes. 1ra ed. Aguascalientes, México: Universidad Autónoma de Aguascalientes; 2012.

8. Delaplane KS, van der Steen J, Guzman-Novoa E. Standard methods for estimating strength parameters of *Apis mellifera* colonies. J Apic Res 2013;52(1): 1-12.

9. Guzmán-Novoa E, Correa BA, Espinosa MLG, Guzmán G. Colonización, impacto y control de las abejas melíferas africanizadas en México. Vet Méx 2011;42(2):149-178.

10. Zarr JH. Biostatistical analysis. . Upper Saddle River, New Jersey: Prentice Hall; 1999.

11. SAS. SAS User´s Guide: Statistics (version 9 ed.). Cary NC, USA: SAS Inst. Inc. 2002.

12. Woyke, J. Correlations and interactions between population, length of worker life and honey production by honeybees in a temperate region. J Apic Res 1984;23(3):148-156.

13. Winston ML. The biology of the honey bee. Cambridge Massachusets EU: Harvard University Press; 1991.

14. Schmickl T, Crailsheim K. Inner nest homeostasis in a changing environment with special emphasis on honey bee brood nursing and pollen supply. Apidologie 2004; 35(3):249-263.

15. Brodschneider R, Crailsheim K. Nutrition and health in honey bees. Apidologie 2010;41(3):278-294.

16. Keller I, Fluri P, Imdorf A. Pollen nutrition and colony development in honey bees: part 1. Bee World 2005;(86):3-10.

17. Somerville, D. Fat bees skinny bees. A manual on honey bee nutrition for beekeepers. Australian Government Rural Industries Research and Development Corporation, Goulburn. 2005; 1-142. file:///C:/Users/HDC/Downloads/05-054.pdf. Accessed Jan 13, 2017.

18. Medina-Flores CA, Guzmán-Novoa E, Aréchiga-Flores CF, Aguilera-Soto JI, Gutiérrez-Piña FJ. Effect of *Varroa destructor* infestations on honey yields of *Apis mellifera* colonies in Mexico's semi-arid high plateau. Rev Mex Cienc Pecu 2011;2(3):313-317.

19. Medina-Flores CA, Guzmán-Novoa E, Aréchiga Flores CF, Gutiérrez Bañuelos H, Aguilera Soto JI. Producción de miel e infestación con *Varroa destructor* de abejas africanizadas (*Apis mellifera*) con alto y bajo comportamiento higiénico. Rev Mex Cienc Pecu 2014;5(2):157-170.

20. Zaitoun ST, Al-Ghzawi AM, Shannag HK. Population dynamics of the Syrian Honeybee, *Apis mellifera* syriaca, under semi-arid Mediterranean conditions. Zoology in the Middle East 2000;21(1):129-132.

21. Mondragón L, Spivak M, Vandame R. A multifactorial study of the resistance of honeybees *Apis mellifera* to the mite *Varroa destructor* over one year in Mexico. Apidologie 2005;36(3):345-358.

22. Arechavaleta-Velasco ME, Guzmán-Novoa E. Honey production with fluvalinate-treated and untreated honey bee (*Apis mellifera* L.) colonies in Valle de Bravo, Mexico. Vet Méx 2000;(31):381-384.

23. Medina-Flores CA, Guzmán-Novoa E, Espinosa-Montaño LG, Uribe-Rubio JL, Gutiérrez-Luna R, Gutiérrez-Piña FJ. Frequency of varroosis and nosemosis in honey bee (*Apis mellifera*) colonies in the state of Zacatecas, Mexico. Rev Chapingo Ser Cie 2014;20(3):159-167.