Beekeepers' honeybee colony selection practice in Tigray, Northern Ethiopia

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Abstract

Selection of colonies plays an important role for successful harvesting of desired products from honeybees. The purpose of this study was therefore to assess local knowledge and experience of beekeepers in Tigray regional state of Ethiopia with regard to colony selection and management practices during purchase and multiplication. Respondent selection was carried out based on the existing conventional agroecological zones namely Dega (highland), Kolla (lowland) and Weinadega (midland). Four woredas (districts) from Dega zone, and three from each of Kolla and Weinadega zones were sampled. A total of 185 beekeepers were interviewed to understand the criteria they were using to select colonies. Preference ranking data were indexed using linear programming.

The result indicated that beekeepers were using six local selection criteria namely worker bee population, body color, comb building direction, aggressiveness, honey yield history and age of the colony ordered according to their preference rank from 1 to 6. Beekeepers understood that selection of honeybee colonies was important because productivity, management easiness and agroclimatic adaptation of colonies are different for different colonies. As a result colonies with dominant black colored bees were chosen as first priority for their merits of better honey productivity, tolerance to absconding and multiplication easiness in Weinadega and Kolla agroecologies. However, red/yellowish colored bees were preferred in Dega agroecology.

Key words : Agroecology, *Apis mellifera*, color, linear programming , productivity

Introduction

Tigray region is one of the potential and well known honey producing regions in Ethiopia. It is known for its good quality white honey. Farmers in the region have long experience of traditional beekeeping. The efforts made to improve this sub-sector from traditional practice to improved technologies is being challenged by shortage of beekeeping input materials, drought, lack of

management skill and associated effects of pest(Chala et al 2012; Gangwar et al 2010 ; Gizachew et al 2013 ; Workneh and Ranjitha 2011).

The productivity of honeybee colonies in Tigray region varies from 6-25kg/hive/year using traditional hives (CSA 2013;Gidey et al 2012;Melaku et al 2013; Teferi et al 2011) , and 16-50kg/hive/year from modern box hives (CSA 2013; Gebreagziabher et al 2014 ; Gidey et al 2012; Haftom and Awet 2013 ;Melaku et al 2013; Teferi et al 2011). This huge variation might be as the result of variations in availability of bee flora, differences in management practice of farmers, exposure of apiary sites to different pests and climatic fluctuations over seasons and years. Adaptation of different honeybee races might also count on the huge variability of the productivity since previous researches identified that *Apis mellifera jementica, Apis mellifera scutelata* and*Apis mellifera monticola* bee races exist in Tigray regional state (Amssalu et al 2004; Nuru 2002).

Genetic variation together with the existing environmental condition are known to affect the choice of foraging in honeybees (Pankiw and Page 2001 ; Pankiw et al 2002) and quantity of honey produced consequently. Selection of honeybee colonies adapted to local conditions is therefore an important step to be successful in the beekeeping sector. Worldwide experiences showed that selection of honeybee colonies could be made on the basis of disease resistance, drought tolerance, hygienic behavior, aggressiveness, tendency of swarming and tendency of propolis collection.

Farmers in Tigray region of Ethiopia have developed their own selection criteria from their long years of beekeeping experience. The purpose of this paper is thus to evaluate and document the local knowledge and experience of colony selection during multiplication and marketing of honeybee colonies so as to shed light on possible improvements on the sub-sector for improved benefits.

Materials and Methods

Study area description

The study was conducted in Tigray regional state of Ethiopia. The region is located within 12^{o}12'05"-14^{o}51'28" Northing and 13 ^{o}43'13"-39 ^{o} 59'45" Easting.

The conventional agroecological zonation in Tigray contains three main divisions: the *Kolla* – lowland (1400-1800 meters above sea level) with relatively low rainfall and high temperatures; the *Weina dega* – midland (1800-2400 m.a.s.l.) with medium rainfall and medium temperatures; *Dega* – highland (2400-3400 m.a.s.l.) with somewhat higher rainfall and cooler temperatures (Hurni 1998).

Sampling and data collection methods

Based on the experience and extent of beekeeping activities in Tigray, ten representative *woredas* (districts) were selected using the agroecological zones- Kolla, Weinadega and Dega- used as strata. Thus, four woredas from *Dega* and three woredas each from both *Weinadega* and *Kolla* agroecological zones were sampled purposively as follows:

- *Dega* : Atsbi Wemberta, Degua Tembien, Ofla and Enda Mehoni *woredas*
- *Weinadea* : Klite Awlaelo, Ahferom and Medebay Zana *woredas*
- *Kolla* : Kafta Humera, Kola Tembien and Tanqua Abergelle *woredas*

From each agroecologically representative *tabias*, 20-25 beekeepers were randomly selected and interviewed. A total of 185 beekeepers were interviewed using structured and semi-structured

questionnaires. Farmers were given the opportunity to list and rank the different colony selection criteria and honeybee types.

Data Analysis Methods

Simple descriptive statistics measures (mean, standard deviation, and percent values) were used to summarize the nature of respondents, experience of beekeeping and their management methods. Pearson correlation was employed to examine the relationship between selection criteria during respondents' choice of honeybee colonies.

Preference scores made on selection criteria and honeybee types were used to identify the most important and commonly used criteria and honeybee type using linear programming model after Wang et al (2007). The model considers the following assumptions to extract preference weights. Let *wj* be the relative importance weight attached to the j^{th} ranking place *(j*=1, . . . ,*m)* and *vij* be the vote of selection criteria *i* being ranked in the j^{th} place. The total score of each selection criteria/bee type is defined as

$Zi = \sum vijwj$, $i = 1, \ldots, n$

Linear programming model (LP-1) was used to calculate the wj values and final ranking among the different selections by respondents. Here follows the model description and assumptions after Wang et al (2007).

LP-1

$$Maximize \propto$$

$$s.t \;\; Zi = \sum_{j=1}^{m} viwj \geq \propto, \qquad i = 1.....n;\ j = 1.....m$$

$$w1 \geq 2w2 \geq \cdots mwm \geq 0$$

$$\sum_{j=1}^{m} wj = 1$$

Microsoft excel solver was used to calculate wj (weight values) for the linear program ranking methods according to the assumptions made above for LP-1.

Results and discussion

Socioeconomic characteristics of respondents

The average age of respondents within the three agroecologies ranges from 40.8±11.8 to 45.3±10.03 years in Kolla and Dega respectively. Most aged beekeepers were found in Dega agroecology. Land ownership in the form of cultivated land, non cultivated compound area and irrigable land was significantly large ($p<0.05$) in Kolla agroecology (Table 1). Similarly cattle and small ruminant ownership was significantly higher ($p<0.05$) in Kolla agroecologoy. However the number of colony ownership was found to be lower ($p<0.05$) in Kolla agroecology when compared with Dega and Weinadega (Table 2).

Table 1: Socioeconomic characteristics of respondents

Socio-economic parameters	Agroecology	Mean	Std. Deviation	P value
	Dega	45.3[a]	10.03	<0.05
Age	Weinadega	43.8[a]	12.4	
	Kolla	40.8[b]	11.8	
Land ownership				
Cultivated land	Dega	1.96 [b]	1.45	<0.001
	Weinadega	2.08 [b]	1.91	
	Kolla	4.94 [a]	4.76	
Compound area	Dega	.59 [b]	0.884	<0.05
	Weinadega	.59 [b]	0.659	
	Kolla	1.65[a]	3.71	
Irrigable land	Dega	.20 [b]	0.718	<0.001
	Weinadega	.28 [b]	0.560	
	Kolla	1.56 [a]	3.60	
Livestock ownership				
Cattle	Dega	4.19 [b]	3.34	<0.05
	Weinadega	4.02 [b]	2.66	
	Kolla	6.85 [a]	7.45	
Equine	Dega	1.95 [a]	2.23	<0.001
	Weinadega	.92 [b]	0.954	
	Kolla	.94 [b]	1.02	
Shoat	Dega	7.22 [b]	12.1	<0.001
	Weinadega	2.81 [b]	4.54	
	Kolla	11.8 [a]	14.9	
Poultry	Dega	3.08 [a]	4.53	>0.05
	Weinadega	1.36 [b]	2.71	
	Kolla	2.96 [a]	4.23	
Family size	Dega	6.37	1.74	>0.05
	Weinadega	6.56	2.07	
	Kolla	6.19	2.35	

[ab] *Means in the same row sub tables with different superscript letters are significantly different at p<0.05*

Beekeeping practice in Kolla appeared to be a recent activity, compared with Dega and Weinadega as most of respondents had less than five years of engagement in the beekeeping sub-sector (Table 2). On the other hand more than 50% of the colonies in Kolla were managed in modern /European box/ hive (Table 3). This is an indication of recent involvement of the government and non-governmental institutions to modernize the beekeeping sub-sector.

Table 2: Beekeeping experience across agroecologies

Agroecology	Beekeeping experience, years						
	< 5	6-10	11-20	>20	Mean	SD	Max
Dega	19(31.7%)	20(33.3%)	12(20%)	9 (15%)	11.48[a]	9.72	40
Kolla	33(50.8%)	17(26.1%)	10 (15.4%)	5 (7.7%)	8.06[b]	7.85	40
Weinadega	21(35.6%)	16(27.1%)	14(23.7%)	8(13.6%)	12.8[a]	13.43	65

[ab] *Means in the same column with different superscript letters are different at p<0.05*

It was observed that the mean number of honeybee colonies managed under European box hive in Kolla and Weinadega was relatively higher than Dega. Whereas larger number of bee colonies in traditional hive were found in Dega agroecologies (Table 3). We found that the largest colony ownership per household in both hive was recorded in Weinadega agroecology which might be due to the suitability of this agroecology for beekeeping practice.

Table 3: Ownership of colonies managed under traditional and modern beehives per household across agroecologies.

Agroecology	Ownership of colonies in both hives per HH				Ownership of colonies in traditional hive per HH				Ownership of colonies in European box hive per HH			
	Mean	Min	Max	SD	Mean	Min	Max	SD	Mean	Min	Max	SD
Dega	7	1	75	11	4	0	40	7	2	0	30	4
Kolla	5	1	27	5	2	0	13	3	3	0	24	4
Weinadega	9	1	101	15	2	0	26	4	6	0	100	14

Source of colonies at the start of beekeeping

The experience of colony selection can start from the beginning of establishing apiary site in ones homestead or closure area. The survey result indicated that large number of small scale beekeepers in Tigray region of Ethiopia obtained their colony from swarm catching (50.6%) (Table 4) followed by purchasing and inheritance. The proportion of swarm catching was the highest in Kolla agroecological zones (81.5% of respondents from Kolla) , Dega (40%) and Weinadega (32.2%). This might be due to the reason that warm weather encourages honeybees to swarm abundantly from hives and wild nests at the beginning of swarming season due to the availability of fast growing and flowering grasses, forbs and shrubs.

Purchasing colonies from other beekeepers was more practiced in Weinadega (58.9%) and Dega (50%) agroecological zones than in Kolla (Table 4). Beekeepers in Dega and Weinadega also had more experience in beekeeping such that colony marketing was better exercised.

Data on sources of the colonies (Table 4) indicated that there were many new farmers who were integrating beekeeping with their farming practice due to increased awareness of farmers on the contribution of beekeeping to support their livelihood.

Table 4: Source of colonies (values in parenthesis are percentages out of respondents in the same agroecology)

A	Transferred from parents (N=261)		Swarm caught (N=259)		Purchased from others (N=247)	
	Yes	No	Yes	No	Yes	No
Dega	21(23.3%)	69(76.6%)	36(40%)	54(60%)	45(50%)	45(50%)
Kolla	10(12.4%)	71(87.7%)	66(81.5%)	13(16.1%)	16(19.8%)	55(67.9%)
Weinadega	15(16.7%)	75(83.3%)	29(32.2%)	61(67.8%)	53(58.9%)	33(36.7%)
Total	46(17.6%)	215(82.4%)	131(50.6%)	128(49.4%)	114(46.2%)	133(53.9%)

Honeybee colony selection criteria

Like other livestock classes, beekeepers in Tigray region carried out honeybee colony selection based on characteristics of worker bee population, body color (usually abdominal pigmentation), direction of comb building, aggressiveness, honey yield history and age of the colony. The population of worker bees in the colony, color of bees and direction of comb building were the first three most important parameters (Table 5). Aggressive behavior, previous honey yield history and age of the colony were ranked lowest.

Table 5: Colony selection criteria used by beekeepers across agroecologies ranked by linear programming model of Wang et al (2007) (Where the weights for LP1 were w_1=0.408, w_2=0.204, w_3=0.136, w_4=0.102, w_5=0.0816, w_6=0.068)

	Dega		Kolla		Weinadega	
	Score	Rank	Score	Rank	Score	Rank
Bee population	28.3	1	26.2	1	27.8	1
Body color	12.6	2	10.7	2	12.9	2
Comb-direction	6.93	3	5.67	3	6.84	3
Aggressiveness	4.09	4	4.67	4	4.26	4
Honey yield history	3.59	5	2.6	5	3.1	5
Age of the colony	2.58	6	2.18	6	2.8	6

Worker bee population, aggressiveness and honey yield history were also recommended characteristics for selection from beekeepers around the world (Büchler et al 2013). The use of color however is unreliable due to hybridization phenomenon. *Apis mellifera yementica* for example show both dark and red/yellow/ colors according to the morphometeric study in Ethiopia (Amssalu et al 2004). Similarly the direction of comb building can be changed by guidance through smearing molten wax in transitional hives and using foundation sheet in European box hives as evidenced by the study of Adgaba et al (2012) in Ethiopia. However the direction of comb building creates difficulty during colony inspection in traditional hives where guidance is not easy to carry out.

Beekeepers recognized that honeybee colonies in Tigray construct their combs in three directions (Difoe, Goni/Seyaf and Salah). Salah is the one where combs are built parallel to the length of the traditional hive and Difoe is perpendicular to the long side of the hive. Goni or Seyaf are built neither perpendicular nor parallel to the length but slanting along the length by some angles to the width (Figure 1). These characteristics were less frequently seen in European box hive where colonies are guided to construct combs along the frames on the foundation sheet. In traditional hives, farmers prefer honeybee colonies that construct their comb in parallel pattern to the length side, as this facilitates harvesting. Identification of the ripe honey combs and occasional inspection is easier if bees construct their comb in parallel pattern along the length side of the hive.

Figure 1: Comb building direction of honeybees in Tigray: (a) Difoe, (b) Goni/Seyaf (c) Salah

Despite the questionable reliability of body color as a selection parameter, beekeepers categorized the color of honeybee colonies as black, mixed and red (yellow) from observation of the abdominal segment color. Mixed colored colonies are those that have some individual worker bees black and others with reddish/yellowish abdominal hair color in the same hive. Most honeybees in the highland area were black in color and those in the midland and lowland wee red/yellow which is in agreement with previous studies (Amssalu et al 2004). Beekeepers also reported that productivity

potential and adaptation of different colored honeybees was dependent on the agroecological and geographical location in the region.

Beekeepers experience on characterizing black, red and mixed colored bees

Beekeepers in the three agroecological zones evaluated the three category of colonies with respect to honey yield, dry season brooding ability, aggressiveness, absconding behavior and swarming tendency.

The black colored bees stood first in honey production according to the interviewed beekeepers in Kolla and Weinadega agroecological zones (Table 6). The black colored bees were also ranked the highest in swarming tendency in all the agroecological zones. Beekeepers explained that the black colored bees were easier for multiplication by splitting due to their high swarming tendency. Black colored bees were considered to be the best honey yielding with high brooding ability during the dry season which made them resistant to drought. Black colored colonies were also reported to be resistant to enemy attacks that cause the bees to abscond. It was only in Dega agroecologies that the red colored bees were preferred to black and mixed colors for honey production. This finding is in contrast to that reported for the Bale highlands, in the south east part of Ethiopia, where black colored bees were better honey producers than the red colored ones (Bogale 2009).

Table 6: Beekeepers response on characterization of red, black and mixed colored bee colonies (rank calculated based on LP1 method (Wang et al 2007)

Colony selection criteria		Dega		Kolla		Weinadega	
		score	rank	score	rank	score	rank
Honey yield	Red	29.53	1	24.8	2	19.92	2
	Black	26.33	2	25.36	1	20.20	1
	Mixed	23.40	3	19.05	3	16.16	3
Brooding ability	Red	20.33	3	21.06	2	16.53	3
	Black	36.39	1	32.02	1	26.39	1
	Mixed	21.10	2	18.65	3	16.69	2
Aggressiveness	Red	18.50	3	20.22	2	17.57	3
	Black	40.77	1	38.13	1	41.05	1
	Mixed	21.08	2	19.63	3	19.99	2
Absconding	Red	33.57	1	30.93	1	25.57	1
	Black	18.24	3	17.15	3	16.71	2
	Mixed	21.38	2	18.84	2	16.69	3
Swarming tendency	Red	20.61	2	23.16	2	17.26	2
	Black	31.02	1	31	1	24.38	1
	Mixed	20.49	3	20.11	3	16.88	3
Colony price	Red	6.875	2	4.615	1	9.25	1
	Black	8.525	1	4.165	2	8.7	2
	Mixed	4.685	3	3.875	3	7.06	3

The mixed colored bees had intermediate properties and didn't have stable external body colors due to hybridization. In general, beekeepers' experience in Tigray region showed that the external body color of honeybees was related to production parameters. The ranking results showed that beekeepers' observations on brooding ability, aggressiveness and swarming tendency were similar

across the three agroecologies. However, their observations on productivity showed variation from other region beekeeper in Ethiopia.

The economic value of honeybees in Tigray is not only for honey but also from selling the colonies such that about 70% of the beekeepers in Dega agroecology were earning income from this practice. The use of beeswax was relatively the highest in the Dega agroecology (28.1%) compared to Kolla (15.9%) and Weinadega (24.4%). The contribution of honeybee colonies to crop pollination services was the least recognized by beekeepers in Tigray region. This requires further awareness creation to let beekeepers know the benefits from bees for pollination as this will add more value to honeybees and beekeeping practices.

Conclusions

- Beekeepers recognized that honey productivity, ease of management and agroecological adaptation of colonies vary according to bee color, initial population of the colony and comb building orientation as the three primary selection criteria.
- Despite their aggressiveness, black colored bees were the most preferred with regard to high honey yield, tolerance of absconding and multiplication easiness in Kolla and Weinadega agroecologies. Whereas red/yellowish colored bees were preferred by beekeepers in Dega agroecology.

Acknowledgements

The authors would like to thank Africa Brazil and LAC Agricultural Innovation Market Place for the financial support to carry out the research activities in the project registered as ID 230. We are also grateful to beekeepers in Tigray Regional state of Ethiopia for their cooperation during the research work.

References

Adgaba N, Al-Ghamdi A A, Chernet M H, Ali Y A, Ansari M J, Radloff S E and Howard R H 2012 An Experiment on Comb Orientation by Honey Bees (Hymenoptera: Apidae) in Traditional Hives. *Journal of economic entomology, Volume 105(3).*

Amssalu B, Nuru A, Radloff S E and Hepburn H R 2004 Multivariate morphometric analysis of honeybees (Apis mellifera) in the Ethiopian region. *Apidologie, Volume 35(1).*

Büchler R, Andonov S, Bienefeld K, Costa C, Hatjina F, Kezic N and Wilde J 2013 Apis mellifera queens. *Journal of Apicultural Research, Volume52 (1).*

Chala K, Taye T, Kebede D and Tadele T 2012 Opportunities and challenges of honey production in Gomma district of Jimma zone, South-west Ethiopia. Journal of Agricultural Extension and Rural Development, Volume 4, Article *# 01B04132942*, Retrieved October 20, 2015, from http://academicjournals.org/journal/JAERD/article-abstract/01B04132942.

CSA 2013 Central statistical agency agricultural sample survey 2012/13 [2005 e.c.]: Report on Livestock and Livestock Characteristics (Private Peasant Holdings), Federal Democratic Republic of Ethiopia Central Statistical Agency, Addis Ababa, Ethiopia.

Gangwar S K, Ebrahim A, Gebremariam H and Tajebe S 2010 Characteristics of honey produced by different plant species in Ethiopia. *Advance in Bioresearch, Volume1(1),* Retrieved February 21, 2015, from http://soeagra.com/abr/vol1/101-05.pdf.

Gebreagziabher A, Mohammed T, Gangwar SK, Girmay G and Girmay T 2014 Performance of Apis mellifera spp. on Honey and Beeswax Production in Different Type of Beehives in Enda Mekoni Woreda, Tigray Region, Ethiopia. *Global Journal of Bio-Science and Biotechnology, Volume 3(3),* Retrieved June 20, 2015, from http://scienceandnature.org/GJBB_Vol3%283%292014.php.

Gidey Y, Bethelhem K, Dawit K and Alem M 2012 Assessment of beekeeping practices in Asgede Tsimbla district, Northern Ethiopia: Absconding, bee forage and bee pests. *African Journal of Agricultural Research, Volume7(1),* Retrieved March15, 2015, from http://www.academicjournals.org/journal/AJAR/article-full-text-pdf/E0D605732836.

Gizachew G, Sefinew A, Amssalu B and Malede B 2013 Prevalence and associated risk factors of Bee Lice in Holeta and its surroundings, Ethiopia. *Journal of Veterinary Science & Technology, Volume 4(130).*

Haftom G and Awet E 2013 On farm evaluation of Kenyan Top bar hive (KTBH) for honey production in Tigray Region, Northern Ethiopia. *Livestock Research for Rural Development. Volume 25, Article #86,* Retrieved March 21, 2014, from http://www.lrrd.org/lrrd25/5/haft25086.htm.

Hurni H 1998 Agroecological Belts of Ethiopia. Explanatory notes on three maps at a scale of 1, 1.

Melaku B, Girmay M and Bereket G 2013 Identifying beekeepers' adaptation strategies in response to climate change in Tigray, Ethiopia. *Wudpecker Journal of Agricultural Research, Volume 2(5),* Retrieved on May 17,2015, from http://www.wudpeckerresearchjournals.org/WJAR/pdf/2013/May/Berhe%20et%20al.pdf.

Nuru A 2002 Geographical races of honeybees of the northern regions of Ethiopia, Rhodes University, Grahamstown, South Africa.

Pankiw T and Page R E 2001 Genotype and colony environment affect honeybee (Apis mellifera L.) development and foraging behavior. *Behavioral Ecology and Sociobiology, Volume 51(1).*

Pankiw T, Tarpy D R and Page R E 2002 Genotype and rearing environment affect honeybee perception and foraging behaviour. *Animal Behaviour, Volume 64(4).*

Solomon B 2009 Indigenous knowledge and its relevance for sustainable beekeeping development: a case study in the Highlands of Southeast Ethiopia. *Livestock Research for Rural Development. Volume 21, Article #184.* Retrieved October 23, 2015, from http://www.lrrd.org/lrrd21/11/boga21184.htm

Teferi M, Yirga G, Hailemichael T and Amare S 2011 Prospects of beekeeping in the Northern Ethiopian highlands. *Scientific Research and Essays, Volume 6(29),* Retrieved June 15,2015, from http://www.academicjournals.org/article/article1380879880_Teferi%20et%20al.pdf.

Wang Y, Chin K and Yang J 2007 Three new models for preference voting and aggregation. *Journal of the Operational Research Society, Volume58(10).*

Workneh A and Ranjitha P 2011 Beekeeping sub sector challenges and constraints in Atsbi Wemberta District of eastern zone, Tigray Region, Ethiopia. *Journal of Agricultural Extension and Rural Development, Volume 3(1),* Retrieved May 08, 2015, from http://www.academicjournals.org/article/article1379423991_Abebe%20and%20Puskur.pdf.

Received	Accepted	Published
13 November 2015	5 April 2016	1 May 2016