Journal of Agriculture Science & Technology JAGST 23 (5) 2024, 93 - 111

Beekeepers' perception of the suitability of climate-smart compliant bee-hive technologies in honey production: The case of Nyandarua and Kajiado counties

Philip Siminyu[1], Fredah Maina[2], Adonijah Oginga[2], Itambo Malombe[3], Mary Gikungu[3]

[1]*Department of Agricultural Economics, University of Nairobi*
[2]*Kenya Agricultural & Livestock Research Organization*
[3]*National Museums of Kenya*

Corresponding author email: Fredah.Maina@kalro.org

ABSTRACT
With increased climate-related challenges, beekeeping practices need to adopt climate-smart technologies to ensure high colonization rates and security against human and animal destruction. This study assessed beekeepers' perception of the suitability of bee hive technologies for honey production. The study tested the hypothesis that improved bee hive technologies do not increase honey production. A multinomial Logit (MNL) regression model was used to analyze data from 428 randomly selected beekeepers in 2 sub-counties each of Kajiado and Nyandarua Counties where the Kenya Climate Smart Agriculture Project (KCSAP) is being implemented. Most beekeepers preferred the Kenya Top Bar hives (41%) and the Langstroth (36%). Based on the significant MNL at $P < 0.01$, this study concluded that honey productivity is influenced by the preference of the bee hive types. There is a need for enhanced training in beekeeping on climate-smart practices to increase the adoption of improved hive technologies and honey production.

Keywords: Apiculture, Bee hives, Beekeepers perceptions, Honey quality

1.0 Introduction
Beekeeping plays an important role in enhancing food security, economic growth, biodiversity conservation, and community livelihoods (Chazovachii *et al*., 2013). According to Chesang *et al*., (2024), economic and social factors, including employment creation, land productivity, and improved economy, play a significant role in the likelihood of residents. According to Feketéné Ferenczi *et al*., (2023), beekeeping is a positive externality for environmental sustainability and contributes to the ecological balance and pollination, which are essential for agricultural productivity. According to Bond *et al*., (2021), honey production can be increased through the reduction of bee movement stresses in search for forage with the planting of bee flora where the bee hives are located. Teklay (2011) recommends the introduction of drought-resistant bee flora species in the dry season, especially in cultivated rain-fed land close to the bee hives. When honey bee colonies are crowded together, competition for forage resources can result in a decline in honey production and colony health, which is resolved by the beekeepers establishing diverse bee forage on their farms that provide good honey production resources all year round (Abbott 2018).

URL: https://ojs.jkuat.ac.ke/index.php/JAGST
ISSN 1561-7645 (online)
doi: 10.4314/jagst.v23i5.6

The effects of climate change are being observed on ecosystems and species in all regions of the world due to the rise in global mean temperature (Leemans & Eickhout 2004). Farmers are amongst the most vulnerable and affected communities exposed to the effects of climate change and climate variabilities (Thorlakson & Neufeldt 2012). According to Cui and Corlett (2016), climate is a major control on the distribution of bees and influences the services they provide. According to Bond *et al*., (2021) the intensity of bee pollination services varies widely across regions, by crop, and even within the same crop family in different locations, this explains why there are variations in bee colonies. When bees move long distances in search for forage there is a reduction in honey production because it is associated with increased colony stress and loss. According to Wright *et al*., (2015) the abundance of bees declined with increasing distance from areas of high forage density. According to Bond *et al*., (2021) bee movement stresses in search for forage can be mitigated with the planting of bee flora where the beehives are located. Planting forage could provide more optimized foraging landscapes for pollinators (Donkersley 2019). Teklay (2011) recommends the introduction of drought resistant bee flora species and set flowers in dry season especially in cultivated rain-fed land.

Climate-smart housing technologies have been proven for high-quality honey and enhance climate resilience in beekeeping. The housing technologies insulate the bee colonies against harsh weather conditions and promote hive security from thieves and honey badgers. The location of the houses depends on the distance from established pastures. Integrated and enriched bee pastures have a direct implication on quality and improved bee health due to availability of high nutritious bee flora.

According to Bond *et al*., (2021), beekeepers can benefit from the services provided by bees by providing framed bee hives, managing the honey collection, inspecting hives and quickly treating any diseases and mites, and controlling colony size and numbers through hive size manipulations. In addition, understanding the challenges specific to the ecological zone is essential for ensuring site-specific solutions are put in place. Beekeeping in arid and semi-arid lands (ASALs) is constrained by high temperatures, predators e.g. honey badgers, and conflict with livestock keeping (Mburu *et al*., 2017). On the other hand, beekeeping in highlands and wet areas is constrained by wetness, safari ants, theft, and low temperature hence the reduced number of harvests as the bees do not go out to forage much during the cold seasons (Rinderer & Hellmich 2019).

About 80% of honey produced in Kenyan ASALs comes from log hives. The hives are often preferred due to reduced absconding during the hot seasons. However, due to the nature of the hives with no separation between the brood chamber and honeycombs, brood and honey mix during harvest, which leads to low honey quality. According to Wambua (2015) beekeepers who used modern hives had higher honey production and management of the hives was easier, with

ISSN 1561-7645 (online)
doi: 10.4314/jagst.v23i5.6

Langstroth hive perceived as being among the most popular modern framed hive and is used in various parts of Kenya. The frames of the Langstroth hives are strong which minimizes breakage, and when the honey is extracted they are returned to the hive leading to less cost in replacing the frames. Use of a queen excluder further increases honey and enhances honey quality (Wambua 2015). Bee housing is important for increased safety, colony management, temperature management and hence results in increased occupancy and hence increased hive products as well as pollination services, (Kebede & Adgaba 2011).

The Kenya Top Bar hive has been tested and validated for high-quality honey production with an emphasis on the affordability and availability of bee hive construction materials. The construction materials are modeled to insulate the bee colonies against harsh weather conditions and also promote hive security from thieves and honey badgers. Providing the honey bee colonies with an insulation material helps to reduce the internal temperature without preserving the continuous evaporation of water, improving the efficiency of bees in converting resources to honey and other hive products (Abou-Shaara *et al*., 2013). A percentage increase in modern hive type causes an increase in the quantity and quality of honey produced (Vural & Karaman 2009). Honey yield doubles in hives placed near forage sources compared to those established far away from forage sources (Sande *et al*., 2009).

The placement of hives should protect the colonies from harsh weather and reduce the distance to preferred bee flora. With increased climate-related challenges, bee hives need to be climate smart to ensure high colonization rates and security against human and animal destruction. The quantity and quality of honey is directly tied to the floral resources available throughout the growing season (Simanonok *et al*., 2020).

Planting forage could provide more optimized foraging landscapes for pollinators, leading to increased agricultural production, as bees provide pollination services and maintain the ecosystem balance (Donkersley 2019).

The objective of this study was to assess beekeepers' preferred climate-smart bee hive technologies for increased honey production. Bee housing is hypothesized to influence the quantity and quality of honey and ease of harvesting hence contributing to pollination as an ecosystem service. How smallholder beekeepers perceive the suitability of climate-smart bee hives and bee housing technologies for honey production is not well known. This study contributes to the lack of knowledge in literature by assessing beekeepers’ perception of the suitability of climate-smart bee hives technologies for honey production. It contributes to knowledge of farmers’ perception of using climate-smart bee hive technologies with increased honey productivity. The hypothesis that using climate-smart bee hive technologies does not increase honey production was tested. This study informs policy on the type of climate-smart bee hive technologies that are suitable for increased honey quantity and quality.

ISSN 1561-7645 (online)
doi: 10.4314/jagst.v23i5.6

2.0 Methodology

2.1 Study area

The study was conducted in Kajiado and Nyandarua counties, purposively selected since the Kenya Climate Smart Agriculture Project (KCSAP), on which this study is based, was upscaling apiculture climate-smart agriculture practices in the counties. Among the key objectives of the project was to validate the suitability of indigenous and modern bee housing technologies in the two counties. Kajiado County comprises semiarid grassland with insufficient rainfall to support rain-fed agriculture with a few isolated pockets with higher elevation and greater precipitation at the foothills of Kilimanjaro and Ngong hills. Agriculture covers a small percentage of the land area, mostly dominated by livestock rearing and wildlife. The rainfall is bimodal with an average of below 500 millimeters over much of the area while Kilimanjaro and Ngong hills receive a little more than 750 millimeters on average. Kajiado County faces interconnected challenges of ecological sustainability, food security, and economic empowerment (Huho *et al*., 2024). Beekeeping has emerged as a promising solution in the County with the potential to address challenges of ecological sustainability, food security, and economic empowerment.

Nyandarua County has an average elevation of 2,216 m asl, ranging from lows of 1,407 m asl to the highest point at 3,975 m asl. The County has good climate quite favorable for diverse agricultural activities. The county has five constituencies: Ol Kalou, Kinangop, Kipipiri, Ndaragwa, and Ol Joro Orok, and 25 wards (Mukami (2018). It has a population of 596,268 and an area of 3,304 square kilometers according to the 2009 general census. Because of the bee flora available from the crops grown in Nyandarua County, beekeeping is thriving well. Because of climate change, the adoption of bee farming in Nyandarua County has been on the reduction.

Beekeeping is relatively new in both Counties and beekeeping was identified as an enterprise for enhancing resilience to climate change by the communities. In both Kajiado and Nyandarua counties, climate change and environmental degradation have been found to influence production, harvesting, collection, storage and marketing of honey, (Mugo *et al*., 2015).

Kajiado West and Kajiado Central Sub-counties in Kajiado County and Kinangop and Ol'Joro Orok Sub-Counties in Nyandarua County were purposively selected for this study.

2.2 Sample size

2.2.1 Sampling and data collection

Multistage sampling was employed in this study within the Counties. In the second stage, Kajiado West and Kajiado Central Sub-Counties in Kajiado County and Kinangop and Ol'Joro Orok Sub-Counties in Nyandarua County were randomly selected based on presence of apiculture farmers in the 4 Sub-Counties. In Nyandarua County beekeepers were sampled from Githabai and Magumu wards in Kinagop sub-county; and Gatimu and Weru wards in Ol'joro Orok sub-county. In Kajiado

URL: https://ojs.jkuat.ac.ke/index.php/JAGST
ISSN 1561-7645 (online)
doi: 10.4314/jagst.v23i5.6

county beekeepers were sampled from Ewuaso Oonkidong'i, and Keekonyokie wards in Kajiado West sub-county; and in Dalalekutuk, Ildamat, Matapato North, and Purko wards in Kajiado central sub-county.

The following formula was used in determining the sample size for an unknown population for this study (Cochran 1963),

$$n = \left(\frac{z * \text{std dev}}{\text{Margin of error}}\right)2$$

Where:
n = the desired sample size from an unknown population
z = confidence interval of the unknown population divided by 2 and checked from the z table 2.98.
Standard deviation of the population was 3.47

Margin of error for the unknown population at 95% confidence interval is 0.5.

$$n = \left(\frac{2.98 * 3.47}{0.5}\right)2 = 427.7$$

$$n \approx 428$$

Since there was no sampling frame for the beekeepers in both counties, the third stage entailed random identification of the first beekeepers. Identifying the possible number of beekeepers within each ward, assigning them proportionately to the respective villages, and using snowballing to get the targeted respondents. In Nyandarua county 245 beekeepers were interviewed and in Kajiado county 183 beekeepers were interviewed. The selected beekeepers were visited by trained enumerators for computer-assisted personal interviews (CAPI) using a pretested semi-structured questionnaire programmed in open data kit (ODK).

2.3 Theoretical framework

This study is based on the random utility model (RUM) which assumes that the beekeeper chooses the climate-smart beehive technology/(ies) of their preference and maximizes the quantity of honey produced subject to the prevailing conditions including climatic factors, management practices, market availability, among others. If the quantity of honey produced using a given climate-smart beehive technology is lower the beekeeper will opt for a climate-smart beehive technology that maximizes the production of honey. The beekeeper has incomplete information and therefore uncertainty has to be taken into account. According to Muriithi (2021), using one climate-smart beekeeping technology is an option for a household. In the case of this study, the objective is to classify the households based on the value of the given predictor variables, therefore, Multinomial Logit (MNL) was considered the best standard method for empirical

ISSN 1561-7645 (online)
doi: 10.4314/jagst.v23i5.6

estimation. In addition, the outcome variable is nominal, further justifying the use of the MNL for analysis.

2.4 The model specification and estimated effects of the independent variables

The Multinomial Logit model is the standard method for estimating unordered, multi-category dependent variables which allows for analyzing data where participants are faced with more than two choices (Gujarati, 2005). The limitations of MNL include the restrictive Independence of Irrelevant Alternatives (IIA) and taste homogeneity assumptions (Bhat *et al*., 2007). Despite its drawbacks, the MNL method has the advantage of permitting analysis of multi-categorical decisions by predicting probabilities of choosing the different options of the outcome variable (Moranga *et al*., 2016). Abdallah and Vulcano (2021) studied the estimation of preferences under a multinomial logit model (MNL), which has increasingly been applied in both industrial and academic practices.

Smallholders' decision to use beehive technologies is made based on their preference for the hive technologies (Masten and Saussier 2000). Smallholder beekeepers prefer beehive technologies that lead to higher honey productivity. Beekeepers' preference for hive technology cannot be directly measured but they are affected by the three major variables namely distance to the nearest watering point for the bees, the occurrence of the plants the bees forage on, and the total quantity of honey harvested (Alemu 2016).

Gujarati (2005) notes that when the dependent variable is an unordered categorical variable, as is the case in this study, MNL is most appropriate. The Multinomial logit has been used in many of the studies dealing with choice, other case examples include use in the choice of animal breeds Murage and Ilatsia, (2010) and in determining the adoption of various milk marketing channels (Mburu *et al*., 2007). According to Cattani *et al*., (2002), preference models based on the MNL formulation are standard in marketing science applications and yield optimal pricing policies that align with observed sales and pricing strategies of firms. This study, therefore, used the Multinomial Logit model to get the preference of beekeepers in using beehive technologies. In addition, analysis of variance (ANOVA) was used to determine the differences in the honey harvested by hive type.

The decision by beekeepers to adopt the hive technologies is estimated, in which the choice of using a given bee hive technology is a function of X composed of the three sets of characteristics: the distance to the nearest watering point for the bees, the occurrence of the plants the bees forage on, and total quantity of honey harvested. The assumption here is that a beekeeper chooses a bee hive technology that maximizes his/her utility subject to several factors where higher utility is obtained (Greene, 2003).

The model can be formally described as follows:

ISSN 1561-7645 (online)
doi: 10.4314/jagst.v23i5.6

Let Y_i represent the beehive technology chosen by a beekeeper. Every beekeeper has several distinct and mutually exclusive alternatives that are assumed to be contingent upon several socioeconomic and institutional attributes, X_i. The MNL model for the selection of a beehive technology specifies the following relationship between the likelihood of choosing alternative Y_i (i=0, 1..., J) and the set of exogenous variables X_i hypothesized to influence choice (Alemu 2016). Therefore, the preference for using a beehive technology is estimated using a multinomial logistic regression model, following Alemu (2016) as:

$$\Pr\left(C_j^* = i\right) = \frac{\exp(\beta_i X_i)}{\sum_{J=1}^{3} \exp(\beta_i X_i)}, j = 1,2,3 \ldots \ldots . . m$$

Where C_j^* the preference of beekeeper *j* choosing alternative *i*
Beehive technologies *i:* 1 = Kenya Top Bar hive, 2 = Langstroth hive, 3 = log hive, and 4 = modified hive.
X_i = vector of household, production, and beekeeping variables
β_i = the vector of coefficients associated with beekeeping

In the Multinomial Logit model (MNL), a baseline alternative, corresponding to the status quo is chosen. This is because one of the options must always be in the respondents' choice set to be able to interpret the results (Hanley *et al*., 2001).

Table 1: Summary of independent variables and the expected signs

Variable	Description and measurement of the variables	Expected signs
County	*Categorical*: 1= Kajiado County 2= Nyandarua County	+/-
Education	Highest level of education of the household head (*Ordinal*): (1 = Secondary and above, 0 = Below Secondary school)	+
Years in beekeeping	Time in years that beekeeping has been practiced (*continuous*)	+
Plant occurrence for bee forage	Occurrence of the plants the bee forage on. *Categorical*: (1 = Grows naturally 0 = otherwise)	+/-
Quality of honey from different sources	Perception on whether the quality of honey differs based on sources of flora. *Categorical:* (0=No; 1=Yes)	+/-
Distance to the watering point	Distance to the nearest watering point for the bees in kilometres (*continuous)*	+/-
Seasons when there are no plants for bees to forage on.	Are there seasons when there are no plants for the bees to forage on (0=No; 1=Yes)	+/-
Sites and locations for beekeeping	Preferred sites and locations for beekeeping (1 = near food crop farm and 0 = otherwise)	+/-
Quantity of honey harvested	The average quantity of honey harvested in kilograms (*continuous)*	+
Landsize	The average size of land in acres (*continuous)*	+/-

To test for multicollinearity among variables fitted in the MNL model, variance inflation factors (VIFs) were calculated (Gujarati 2005). All the explanatory variables had a variance inflation factor (VIF) less than 1.79 and a mean VIF of 1.35. With the explanatory variables having a VIF which was

ISSN 1561-7645 (online)
doi: 10.4314/jagst.v23i5.6

less than 1.79, multicollinearity was ruled out in the model. Multicollinearity exit if a model's VIF is greater than 10 (Gujarati 2005).

3.0 Results and Discussions

3.1 Household characteristics

There were more male than female beekeepers interviewed in all Sub-Counties. According to Lydiah et al., (2019) ,the beekeeping sector remains largely underdeveloped because in many parts of the country, it is still a male-dominated enterprise. The majority of the beekeepers in Kajiado county are in their middle age, between 36 - 50 years while in Nyandarua county are more than 50 years (Table 2), with a mean household size of 6 members across all 4 sub-counties. The majority of the beekeepers had attained secondary education (Figure 1). In Kajiado West Sub-county, among the beekeepers, 32% had tertiary education and 28% had no education, Figure 1. The kind of education a person has attained helps in making decisions on the kind of technology to use (Odini 2014). There were more youths in beekeeping in Kajiado county than in Nyandarua county, Table 2. According to Bullock *et al*., (2023), the potential of the agricultural sector to support youth is large with them engaging in rearing chickens, keeping dairy cows, pigs, and small ruminants, and often rearing a multiple combination of species.

T*able 2: Household characteristics of beekeepers in the 4 sub-counties (% of respondent*s)

Variable	Description	Kajiado West	Kajiado Central	Kinangop	Ol'Joro Orok
Gender of household head	% Male	70	74	83	89
			26		
Age categories of the household heads	youths (18 - 35 years)	30	23	6	9
	36 - 50 years	48	51	36	36
	Over 50 years	23	26	58	55

URL: https://ojs.jkuat.ac.ke/index.php/JAGST
ISSN 1561-7645 (online)
doi: 10.4314/jagst.v23i5.6

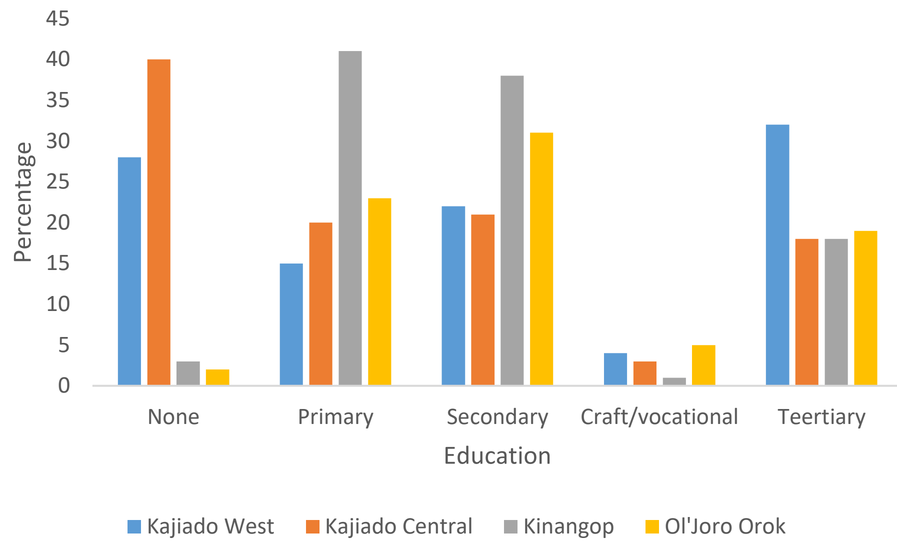

Figure 1: The highest level of education of the household head

Source: Survey Data

3.2 Preferred sites and locations for beekeeping

Majority of beekeepers interviewed in Kajiado West, Kajiado Central, and Kinangop Sub-counties prefer sites and locations for beekeeping away from home while in Ol Joro Orok Sub-County (42%) prefer sites and locations for beekeeping in the forest or natural woodland, Table 3. Honey production positively correlates with the location of the hives, the decline in honey production is due to poor equipment, deforestation, and apiary location (Malisa & Yanda 2016). Malisa & Yanda (2016) recommend for beekeepers to prepare and provide food and water for bees, use framed hives, increase the number of bee hives, and change harvesting methods and time for increased honey production.

Table 3: Preferred sites and locations for beekeeping in each Sub-County (% of respondents)

Preferred sites and locations for beekeeping in each Sub-County	Kajiado West	Kajiado Central	Kinangop	Ol Joro Orok
Near home	58	19	31	26
Near food crop farm	37	10	39	25
In forest/natural woodland	50	32	38	42
Away from home	62	53	51	40
In a bee paddock	21	9	18	6

Source: Survey Data

Among the respondents interviewed, 57% perceived that the quality of honey from different sources differs, with a majority saying that the plants the bees forage on determine the differences in the quality of honey, Table 4. According to De Beer *et al*., (2021) honey produced from other

ISSN 1561-7645 (online)
doi: 10.4314/jagst.v23i5.6

forage types differs significantly from that produced from crops. The difference in plant species from which the honey comes causes differences in the quality of honey (Dobrinas *et al*., 2022).

Table 4: Beekeepers perception of determinants of honey quality in the 4 sub-counties

	Sub counties (% of respondents)			
Quality determinants	Kajiado Central (n=105)	Kajiado West (n=78)	Kinangop (n=157)	Ol'Joro Orok (n=88)
Plants the bees forage on	65	79	61	57
The region where the honey is produced	44	26	35	51
Location of the hives	10	2	2	4
Type of hives	8	0	17	10
Management of hives	6	0	2	6
Time of harvesting the honey	2	0	0	2

Source: Survey Data

3.3 Beehive ownership

Majority of beekeepers in Kajiado West (65%) and Kajiado Central (52%) Sub-counties owned the Kenya Top bar hive and Langstroth hives respectively. Ownership was more diverse in Nyandarua County, majority of respondents in Kinangop (41%) and Ol Joro Orok (38%). All the bee hives are owned by individuals in the 3 Sub-Counties while in Kajiado Central Sub-County 21% of the beekeepers own the bee hives communally, Table 5. The determination of beehive ownership is based on the ownership of the land where the beehives are nesting in the community (Daud 2021), where ownership is having total control (Fiore 2022).

Table 5: Type of bee hives individually owned in the 4 sub-counties

Variable	Description	Sub-county			
		Kajiado West n = 78	Kajiado Central n = 105	Kinangop n = 157	Ol Joro Orok n = 88
Individually owned bee hives	Langstroth hive	80%	15%	39%	23%
	Kenya Top Bar hive	11%	60%	44%	40%
	Log hive	9%	4%	10%	14%
	Modified wooden hive	0%	21%	7%	23%

Source: Survey Data

Majority of beekeepers (at least 60% in Kajiado and 50% in Nyandarua) have their hives hanging from trees. In Nyandarua, close to half of the respondents had an established apiary with stands. Less than 10% of the respondents had bee houses established for their colonies (Figure 2)

ISSN 1561-7645 (online)
doi: 10.4314/jagst.v23i5.6

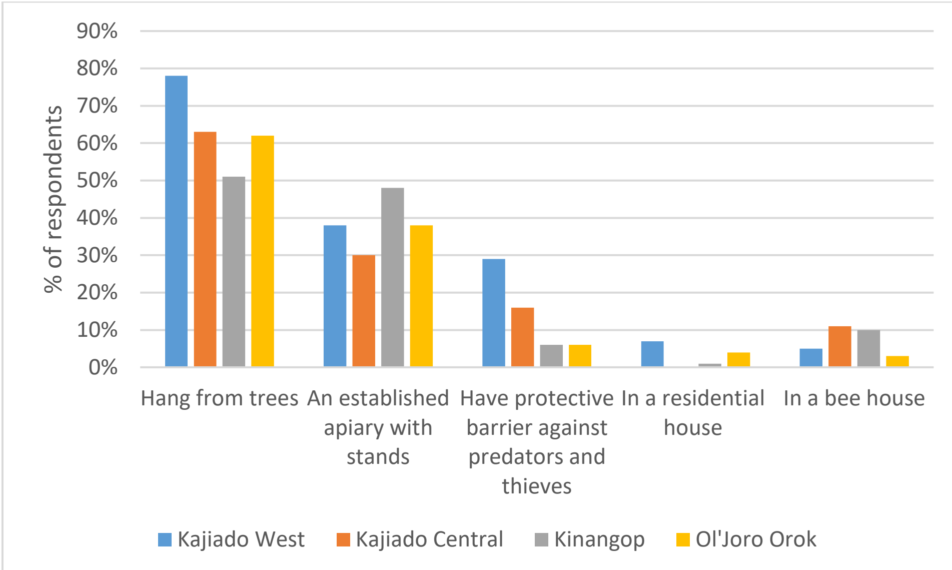

Figure 2: Positioning of beehives by interviewed households (% of respondents)
Source: Survey Data

The respondents attributed easy management to the Kenya Top Bar and Langstroth hives. Beekeepers prefer improved hives because they are easy to manage, Table 6. According to Ande *et al*., (2008) the Kenya Top Bar and Langstroth hives established bee colonies earlier than the other hives making it easy for beekeepers to manage them. Beekeepers stock their hives with feral colonies or hang empty log hives in trees to attract swarms of bees (Schouten *et al*., 2019).

Table 6: Reasons for the preferred hive types by the beekeepers

Reasons for the preferred hive types	Kenya Top Bar hive	Langstroth hive	Log hive	Modified hive
Easy management	88%	80%	56%	73%
More honey	59%	47%	39%	59%
Less absconding	39%	18%	25%	32%
Separates brood from honey	30%	39%	0%	16%
Easier harvesting	77%	71%	53%	55%
Less invasion by animal predators	15%	7%	6%	27%
Less invasion by insect predators	12%	8%	14%	25%
Better quality honey	19%	23%	255	16%

The beekeepers in Kinangop Sub-County mentioned that the main source of water in the region comes from flowing rivers, with 57% of all the beekeepers in the 4 Sub-Counties reporting that they physically provide water for bees in the dry seasons. The beekeepers struggle to keep their bees during the dry seasons leading to low honey harvests hence they are forced to provide water

ISSN 1561-7645 (online)
doi: 10.4314/jagst.v23i5.6

for the bees (King *et al.*, 2017). The average distance to the water sources for bees in Kajiado West and Kajiado Central Sub-Counties was 1 kilometer while that in Kinagop and Ol'Joro Orok Sub-Counties was 0.5 kilometers.

ANOVA was used to see if there were any significant differences between the quantity of honey harvested by hive types. From the ANOVA results there was no significant difference in the quantity of honey harvested from the various hives, as shown by the one-way ANOVA at P < 0.05, Table 7.

Tables 7: Analysis of variance (honey harvested)
Quantity of honey harvested by hive type

Hive type	N	Quantity of honey in Kgs
Langstroth	35	31.7a
KTBH	60	37.8a
Log hive	45	38.8a

F=2.791; p=0.042

3.3.1 Beekeepers' preferred climate-smart bee hive technologies for increased honey production

The highest level of education of the household head negatively and significantly affects the preference for Log hive compared to the Kenya top bar hive at P < 0.05, Table 8. According to Andaregie and Astatkie (2021) the level of education of the household head influences beekeeping adoption. The length of time beekeeping has been practiced negatively and significantly affects beekeepers' preference for log hive compared to the Kenya top bar hive at P < 0.05, Table 8. Depending on the length of time beekeeping has been practiced, the probability that a beekeeper chooses the log hive over the Kenya top bar hive is negative 11 percent. Honey is harvested more than once in the same year depending on the length of time beekeeping has been done and bee management skills (Kumsa & Takele 2014). Beekeeping has been practiced since ancient times and can act as an additional source of income for farmers in rural areas for poverty alleviation (Agera 2011).

The quality of honey from different sources differs significantly and positively affects the beekeepers' preference for a modified hive compared to the Kenya top bar hive, Table 8. Beekeepers who produce different qualities of honey are more likely to prefer the modified hive compared to the Kenya top bar hive, Table 8. According to De Beer *et al.*, (2021) different regions produce different qualities of honey, and honey produced from crops differed significantly from all other forage types.

ISSN 1561-7645 (online)
doi: 10.4314/jagst.v23i5.6

Distance to the nearest watering point for the bees in kilometers significantly and negatively affects beekeepers' preference for Langstroth hive, and log hive compared to the Kenya top bar hive at $P < 0.1$. Beekeepers who are near water points are less likely to prefer the Langstroth hive and log hive compared to the Kenya top bar hive, Table 8. To encourage the visitation of bees, beekeepers need to plant scattered trees and maintain a watering point in close vicinity because the presence of watering points has a positive effect on bee species richness (Lentini *et al*., 2012). According to Kinati (2022), Beekeeping is the cheapest eco-friendly approach to promoting the conservation of natural ecosystems in the face of the growing human population and demand for land limiting water access.

Seasons when there are no plants for the bees to forage on negatively and significantly affect the preference for a modified hive compared to the Kenya top bar hive at $P < 0.1$, Table 8. There is a probability of -8 percent for beekeepers to choose the modern hive over the Kenya Top Bar hive during seasons when there are no plants for bees to forage on. When plant resources become more available, foraging bees are capable of exerting significantly more active choice concerning their pollen diet leading to increased honey production (Kajobe 2007). According to Wood *et al*., (2018), the flowering period of plants fills a forage gap and contributes to the diet of honey bees and wild bees during a given season.

Preferred sites and locations for beekeeping positively and significantly affect the preference for a Langstroth hive compared to the Kenya top bar hive at $P < 0.01$, Table 8. Beekeepers are more likely to prefer the Langstroth hive compare to the Kenya Top Bar hive depending on the site for beekeeping. Getting increased beehive activities and increasing honey production requires locating apiary sites that are suitable for bees. Beekeepers prefer sites and locations for beekeeping that have natural forage for the bees, mostly in forested and vegetative areas (Sari *et al*., 2020).

The average size of land in acres positively and significantly affects the preference for a Langstroth hive compared to the Kenya top bar hive at $P < 0.05$, Table 8. The average land size of a farmer determines the rate of adoption of beekeeping because farmers are able to make beehives on their land as they grow other kinds of crops (AYDIN *et al*., 2020).

Table 8: MNL parameter estimates for the preference of hive technologies (Kenya Top_Bar_hive used as base outcome)

Most preferred hive type	Langstroth hive			log hive			modified hive		
	Coefficient.	Robust Std. Err.	P>z	Coefficient.	Robust Std. Err.	P>z	Coefficient.	Robust Std. Err.	P>z
County	-0.463	0.446	0.299	0.002	0.641	0.998	-0.746	0.611	0.222
Highest level of education of the household head	0.049	0.286	0.865	-1.571**	0.636	0.014	-0.143	0.387	0.711

ISSN 1561-7645 (online)
doi: 10.4314/jagst.v23i5.6

Length of time in years beekeeping has been practiced	0.077	0.302	0.799	-1.141**	0.501	0.023	0.121	0.451	0.789
Occurrence of the plants the bee forage on	-0.521	0.351	0.136	-0.394	0.589	0.504	-0.023	0.508	0.965
Do you think the quality of honey from different sources differs	0.960***	0.278	0.001	1.031**	0.466	0.027	0.855**	0.388	0.028
Distance to the nearest watering point for the bees in kilometers	-0.353*	0.198	0.074	-0.441*	0.234	0.061	-0.162	0.139	0.245
Are there seasons when there are no plants for the bees to forage on	-0.034	0.289	0.907	-0.141	0.478	0.768	-0.791*	0.457	0.083
Preferred sites and locations for beekeeping	-1.000***	0.338	0.003	-0.648	0.483	0.181	-0.461	0.394	0.242
The average quantity of honey harvested in kilograms	-0.139	0.395	0.725	-0.702	0.591	0.235	0.108	0.545	0.843
The average size of land in acres	0.008**	0.004	0.021	0.005	0.004	0.195	-0.013	0.011	0.223
Constant	0.108	0.588	0.854	-0.642	0.788	0.415	-0.566	0.791	0.473

n = 333
LR Chi2 (18) = 73.76
Prob > chi2 = 0.0001
Pseudo R2 = 0.1012
Log-likelihood = -359.89
***, **, * significance levels at 1, 5, and 10 percent respectively

4.0 Conclusion and Recommendations

The most preferred hive was Langstroth hives because they had higher production, high occupancy rates, and were easy to manage in cleaning, checking combs, and harvesting. From the findings, climate-smart beehives had higher honey production and occupancy rates in both counties. With the MNL results being statistically significant, this study concluded that beehives that beekeepers prefer influence the honey produced. From the findings, beekeeping is dominated by the male gender. The availability of bee forage makes beekeepers increase modern hives on the farm leading to increased honey production. Honey that is produced from modern hives is of high quality. When bees get forage and water readily available, there will be less movement and honey production will increase. Beekeepers who have practiced beekeeping for longer times will prefer to have hives that lead to increased honey production. Beekeepers prefer hives that are adapted to the sites and locations for beekeeping.

More of the female gender are encouraged to venture into beekeeping for improved livelihoods. Beekeeping training to be increased on climate-smart beekeeping among the beekeepers and non-beekeepers for increased adoption of improved hive technologies and increased honey production. During times when there are no plants for bees to forage, beekeepers are encouraged to plant crops that will provide forage for the bees. Hives that are adapted to different sites and locations should be made available for beekeepers. The national beekeeping institute to

ISSN 1561-7645 (online)
doi: 10.4314/jagst.v23i5.6

strengthen the capacity of beekeepers through climate-smart apiculture training for them to embrace climate-smart beekeeping that increases honey production and conserves the environment.

5.0 Acknowledgment

The authors acknowledge the Kenya Climate Smart Agriculture Project (KCSAP) under the Kenya Agricultural and Livestock Research Organization (KALRO) for providing financial support for this study and all the collaborators from the National Museums of Kenya for sparing their time to provide input towards the improvement of this study. The beekeepers in Kajiado county and Nyandarua county for providing valuable information on the status of apiculture production through interviews.

Consent was sought from the respondents before begining the interview and there was no ethical concern in the study.

6.0 References

Abou-Shaara, H.F., Al-Ghamdi, A.A. and Mohamed, A.A., 2013. Honey bee colonies performance enhance by newly modified beehives. Journal of Apicultural Science, 57(2), pp.45-57. https://doi.org/10.2478/jas-2013-0016.

Abbott, C., 2018. How to avoid the crowds. American Bee Journal.

Abdallah, T., & Vulcano, G. (2021). Demand estimation under the multinomial logit model from sales transaction data. Manufacturing & Service Operations Management, 23(5), 1196-1216. https://doi.org/10.1287/msom.2020.0878

Agera, S.I.N., 2011. Role of beekeeping in the conservation of forests. Global Journal of Agricultural Sciences, 10(1), pp.27-32. https://www.ajol.info/index.php/gjass/article/view/79068.

Alemu, A. E. (2016). Determinants of smallholders' preference to hybrids – prospect for upgrading to high-value food chains. J. Agribus. Rural Dev., 3(41), 237–247. DOI: 10.17306/JARD.2016.50

Ande, A.T., Oyerinde, A.A. and Jibril, M.N., 2008. Comparative study of the influence of hive types on bee colony establishment. International Journal of Agriculture and Biology, 10(5), pp.517-520. https://www.researchgate.net/profile/Akeem-Oyerinde-2/publication/242145336_Comparative_Study_of_the_Influence_of_Hive_Types_on_Bee_Colony_Establishment/links/55a7943a08aeceb8cad63be2/Comparative-Study-of-the-Influence-of-Hive-Types-on-Bee-Colony-Establishment.pdf.

Andaregie, A., & Astatkie, T. (2021). Determinants of beekeeping adoption by smallholder rural households in Northwest Ethiopia. Cogent Food & Agriculture, 7(1), 1954817. https://doi.org/10.1080/23311932.2021.1954817.

ISSN 1561-7645 (online)
doi: 10.4314/jagst.v23i5.6

AYDIN, B., Aktürk, D., & Arsoy, D. (2020). Economic and efficiency analysis of beekeeping activity in Turkey: Case of Çanakkale Province. Ankara Universitesi Veteriner Fakultesi Dergisi, 67(2). DOI: 10.33988/ auvfd.571371

Bhat, C.R., Eluru, N. and Copperman, R.B., 2007. Flexible model structures for discrete choice analysis. In Handbook of Transport Modelling: 2nd Edition (pp. 75-104). Emerald Group Publishing Limited. https://doi.org/10.1108/9780857245670-005.

Bond, J.K., Hitaj, C., Smith, D., Hunt, K., Perez, A. and Ferreira, G., 2021. Honey Bees on the Move: From Pollination to Honey Production and Back.

Bullock, R. M., Miriti, P., & DuttaGupta, T. (2023). Young women's and men's climate adaptation practices and capacities in Kenya livestock production systems. Frontiers in Sustainable Food Systems, 7, 1197965. https://www.frontiersin.org/journals/sustainable-food-systems/articles/10.3389/fsufs.2023.1197965/full

Cattani, K., Dahan, E. and Schmidt, G., 2002. Spackling: Smoothing make-to-order production of custom products with make-to-stock production of standard items.

Chazovachii, B., Chuma, M., Mushuku, A., Chirenje, L., Chitongo, L. and Mudyariwa, R., 2013. Livelihood resilient strategies through beekeeping in Chitanga village, Mwenezi District, Zimbabwe. http://dx.doi.org/10.5539/sar.v2n1p124.

Chesang, B. J., Njuguna, M. B., & Munala, G. K. (2024). Urban agriculture and its determinants in Kidfarmaco estate, Kikuyu Town. Journal of Agriculture, Science and Technology, 23(3), 107-119 https://doi.org/10.4314/jagst.v23i3.7.

Cochran 2nd, W.G., Sampling techniques 2nd Edition, 1963 New York.

Cui, Q., & Corlett, R. T. (2016). Seasonal and diurnal patterns of activity in honeybees (Apis spp.) on the northern edge of the Asian tropics; their implications for the climate-change resilience of pollination. Tropical Conservation Science, 9(3), 1940082916667142. https://doi.org/10.1177/1940082916667142.

Daud, M., 2021, November. Nesting habitat and honey production of asiatic honey bees (Apis cerana) in the protected forest in Enrekang Regency, Indonesia. In IOP Conference Series: Earth and Environmental Science (Vol. 886, No. 1, p. 012111). IOP Publishing. https://10.1088/1755-1315/886/1/012111.

De Beer, T., Otto, M., Pretoruis, B. and Schönfeldt, H.C., 2021. Monitoring the quality of honey: South African case study. Food Chemistry, 343, p.128527. https://doi.org/10.1016/j.foodchem.2020.128527.

Donkersley, P., 2019. Trees for bees. Agriculture, ecosystems & environment, 270, pp.79-83. https://doi.org/10.1016/j.agee.2018.10.024

Dobrinas, S., Soceanu, A., Birghila, S., Birghila, C., Matei, N., Popescu, V., & Constanda, L. M. (2022). Chemical Analysis and Quality Assessment of Honey obtained from different sources. Processes, 10(12), 2554. https://doi.org/10.3390/pr10122554.

Feketéné Ferenczi, A., Szűcs, I., & Bauerné Gáthy, A. (2023). Evaluation of the pollination ecosystem service of the honey bee (Apis mellifera) based on a beekeeping model in Hungary. Sustainability, 15(13), 9906. https://doi.org/10.3390/su15139906.

Fiore, A. C. (2022). “No fences in beekeeping”: Social and Spatial Relationships in Beekeeping in Vermont. https://scholarworks.uvm.edu/castheses/112/.

Greene, W., 2003. Econometric Analysis”, Pearson Education, Inc., Upper Saddle River, New Jersey. USA.

Gujarati, D. (2005). Basic econometrics, (4th edition); New Delhi, India: Tata McGraw-Hill.

Hanley, N., Mourato, S. and Wright, R.E., 2001. Choice modelling approaches: a superior alternative for environmental valuatioin?. Journal of economic surveys, 15(3), pp.435-462. https://doi.org/10.1111/1467-6419.00145

Huho, J. M., Macharia, K., Mburu, L. N., & Stober, S. (2024). Apicultural Knowledge for Ecological Sustainability, Food Security and Economic Empowerment: A Case of Kajiado County, Kenya. Africa Journal of Technical and Vocational Education and Training, 9(1), 56-64. http://www.afritvetjournal.org/index.php/Afritvet/article/view/181.

Kajobe, R., 2007. Pollen foraging by Apis mellifera and stingless bees Meliponula bocandei and Meliponula nebulata in Bwindi Impenetrable National Park, Uganda. African Journal of Ecology, 45(3), p.265.

Kebede, A. and Adgaba, N., 2011. Honey Bee Production Practices and Honey Quality in Silti Wereda Ethiopia. Honey bee production practices and honey quality in Silti Wereda, Ethiopia. https://www.researchgate.net/profile/Alemayehu-Kebede/publication/259506523_HONEY_BEE_PRODUCTION_PRACTICES_AND_HONEY_QUALITY_IN_SILTI_WEREDA_ETHIOPIA/links/569496cf08ae3ad8e33b79f9/HONEY-BEE-PRODUCTION-PRACTICES-AND-HONEY-QUALITY-IN-SILTI-WEREDA-ETHIOPIA.pdf.

Kinati, C. (2022). Role of integrating beekeeping with water shade management in Ethiopia. Multidisciplinary Reviews, 5(1), 2022004. https://doi.org/10.31893/multirev.2022004

King, L.E., Lala, F., Nzumu, H., Mwambingu, E. and Douglas-Hamilton, I., 2017. Beehive fences as a multidimensional conflict-mitigation tool for farmers coexisting with elephants. Conservation Biology, 31(4), pp.743-752. https://doi.org/10.1111/cobi.12898.

Kumsa, T. and Takele, D., 2014. Assessment of the effect of seasonal honeybee management on honey production of Ethiopian honeybee (Apis mellifera) in modern beekeeping in Jimma Zone. Research Journal of Agriculture and Environmental Management, 3(5), pp.246-254. file:///C:/Users/USER/Downloads/KumsaandTakele.pdf.

Leemans, R., & Eickhout, B. (2004). Another reason for concern: regional and global impacts on ecosystems for different levels of climate change. Global environmental change, 14(3), 219-228. https://doi.org/10.1016/j.gloenvcha.2004.04.009.

Lentini, P.E., Martin, T.G., Gibbons, P., Fischer, J. and Cunningham, S.A., 2012. Supporting wild pollinators in a temperate agricultural landscape: Maintaining mosaics of natural features and production. Biological Conservation, 149(1), pp.84-92. https://doi.org/10.1016/j.biocon.2012.02.004.

Lydiah, M., Casper, M., Ngare, W., & Immaculate, M. (2019). Gender gaps in decision making power in households: Case of improved bee keeping among the Maasai Community in

ISSN 1561-7645 (online)
doi: 10.4314/jagst.v23i5.6

Trans Mara, Narok county, Kenya. International Journal of Gender Studies, 4(1), 19-36. https://www.iprjb.org/journals/index.php/IJGS/article/view/839.

Odini, S., 2014. Access to and use of agricultural information by small scale women farmers in support of efforts to attain food security in Vihiga County, Kenya. Journal of emerging trends in economics and management sciences, 5(2), pp.80-86. https://hdl.handle.net/10520/EJC152937.

Malisa, G. and Yanda, P., 2016. Impacts of climate variability and change on beekeeping productivity. Bulletin of Animal Health and Production in Africa, 64(1), pp.49-55.

Masten, S. and Saussier, S., 2000. Econometrics of contracts: an assessment of developments in the empirical literature on contracting. Revue d'économie industrielle, 92(1), pp.215-236. https://www.persee.fr/doc/rei_0154-3229_2000_num_92_1_1048.

Mburu, P.D.M., Affognon, H., Irungu, P., Mburu, J. and Raina, S., 2017. Gender roles and constraints in beekeeping: A case from Kitui County, Kenya. Bee World, 94(2), pp.54-59. https://doi.org/10.1080/0005772X.2016.1275490.

Mburu, L., Wakhungu, J.W. and Gitu, K.W., 2007. Determinants of smallholder dairy farmers' adoption of various milk marketing channels in Kenya highlands. Livestock research for rural development, 19, pp.9-18.

Moranga, L.O., Otieno, D.J. and Oluoch-Kosura, W., 2016. ANALYSIS OF FACTORS INFLUENCING TOMATO FARMERS'WILLINGNESS TO ADOPT INNOVATIVE TIMING APPROACHES FOR MANAGEMENT OF CLIMATE CHANGE EFFECTS IN TAITA TAVETA COUNTY, KENYA.

Mugo, M. J., Mutiso, F. M., Cheboiwo, J., Sang, F., & Tarus, G. K. (2015). Floristic composition, affinities and plant formations in tropical forests: A case study of Mau forests in Kenya.

Mukami, N. N. (2018). Analysis Of Technical Efficiency And Welfare Effects Of Snow Peas Production By Small Scale Farmers In Nyandarua County, Kenya. file:///C:/Users/USER/Downloads/NAOMI%20NJERI%20MUKAMI-%20THESIS.pdf.

Murage, A.W. and Ilatsia, E.D., 2011. Factors that determine use of breeding services by smallholder dairy farmers in Central Kenya. Tropical animal health and production, 43, pp.199-207. https://doi.org/10.1007/s11250-010-9674-3.

Muriithi, L. N. (2021). Adoption of Selected Climate Smart Agriculture Technologies among Smallholder Farmers in Lower Eastern Kenya (Doctoral dissertation, University of Embu). http://repository.embuni.ac.ke/handle/embuni/3879

Rinderer, T. E., & Hellmich, R. L. (2019). The processes of Africanization. In The African honey bee (pp. 95-117). CRC Press.

Schouten, C., Lloyd, D. and Lloyd, H., 2019. Beekeeping with the Asian honey bee (Apis cerana javana Fabr) in the Indonesian islands of Java, Bali, Nusa Penida, and Sumbawa. Bee world, 96(2), pp.45-49. https://doi.org/10.1080/0005772X.2018.1564497.

Sande, S.O., Crewe, R.M., Raina, S.K., Nicolson, S.W. and Gordon, I., 2009. Proximity to a forest leads to higher honey yield: Another reason to conserve. Biological conservation, 142(11), pp.2703-2709. https://doi.org/10.1016/j.biocon.2009.06.023.

Sari, F., Kandemir, İ., Ceylan, D.A. and Gül, A., 2020. Using AHP and PROMETHEE multi-criteria decision making methods to define suitable apiary locations. Journal of Apicultural Research, 59(4), pp.546-557 https://doi.org/10.1007/s13592-020-00736-7.

Simanonok, M.P., Otto, C.R. and Smart, M.D., 2020. Do the quality and quantity of honey bee-collected pollen vary across an agricultural land-use gradient?. Environmental entomology, 49(1), pp.189-196. https://doi.org/10.1093/ee/nvz139.

Teklay, A., 2011. Seasonal availability of common bee flora in relation to land use and colony performance in Gergera Watershed Atsbi Wemberta District, Eastern Zone of Tigray, Ethiopia (Doctoral dissertation, Hawassa University). https://cgspace.cgiar.org/server/api/core/bitstreams/e663ecb3-19eb-4c6c-a695-78a89e4d9e54/content.

Thorlakson, T., Neufeldt, H. Reducing subsistence farmers' vulnerability to climate change: evaluating the potential contributions of agroforestry in western Kenya. Agric & Food Secur 1, 15 (2012). https://doi.org/10.1186/2048-7010-1-15

Wambua, B.M., 2015. Assessment of performance indices of frame hive beekeeping and the traditional technology in Kenya a case study of Kitui county (Doctoral dissertation). http://repository.seku.ac.ke/handle/123456789/1315.

Wright, I. R., Roberts, S. P., & Collins, B. E. (2015). Evidence of forage distance limitations for small bees (Hymenoptera: Apidae). European Journal of Entomology, 112(2), 303. http://DOI:10.14411/EJE.2015.028.

Wood, T. J., Kaplan, I., & Szendrei, Z. (2018). Wild bee pollen diets reveal patterns of seasonal foraging resources for honey bees. Frontiers in Ecology and Evolution, 6, 210 https://doi.org/10.3389/fevo.2018.00210.

Vural, H. and Karaman, S., 2009. Socio-economic analysis of beekeeping and the effects of beehive types on honey production. Notulae Botanicae Horti Agrobotanici Cluj-Napoca, 37(2), pp.223-227. https://doi.org/10.15835/nbha3723298.

ISSN 1561-7645 (online)
doi: 10.4314/jagst.v23i5.6