OPEN ACCESS Int. J. Agr. Ext. 13 (01) 2025. 57-67 DOI:-10.33687/ijae.013.01.5474

Available Online at EScience Press
International Journal of Agricultural Extension
ISSN: 2311-6110 (Online), 2311-8547 (Print)
https://esciencepress.net/journals/IJAE

SCREENING OF BEEKEEPING POTENTIAL ON THREE WILD PLANT SPECIES IN NYAMBAKA (ADAMAWA REGION OF CAMEROON)

[a,b]Nentcherse Mbere, [c]Michelson A. Ela*, [d]Njoya M. T. Mogho, [b,e]Tchobsala, [a]Fernand-Nestor T. Fohouo

[a] *Laboratory of Applied Zoology, Department of Biological Sciences, University of Ngaoundere. P.O. Box 454 Ngaoundere, Cameroon.*
[b] *Laboratory of Biodiversity and Sustainable Development, Department of Biological Sciences, University of Ngaoundere. P.O. Box 454 Ngaoundere Cameroon.*
[c] *Laboratory of Entomology, Department of Biological Sciences, University of Maroua, P.O. Box 814 Maroua Cameroon.*
[d] *Laboratory of Entomology, Department of Biological Sciences, University of Bamenda, P.O. Box 39 Bambili.*
[e] *Laboratory of Botany, Department of Biological Sciences, University of Maroua, P.O. Box 814 Maroua Cameroon.*

ARTICLE INFO

Article History
Received: October 12, 2024
Revised: December 08, 2024
Accepted: January 28, 2025

Keywords
Beekeeping
Bee plant
Foraging behavior
Melissopalynology
Nectar
Plant status

ABSTRACT

Beekeeping is one of the most important sources of income for bee farmers in Nyambaka, Cameroon. Understanding the contribution of various plants around apiaries is important for the development of the beekeeping sector. The aim of the present study was to examine the availability and profitability of the food resources harvested by honeybees from the flowers of *Keetia venosa* (Rubiaceae), *Maranthes kerstingii* (Chrysobalanaceae), and *Nicandra physalodes* (Solanaceae) in the study area between June and March 2017/2018 and 2018/2019. Parameters of worker bees' foraging behavior were recorded on the flowers of each of the plant species twice a week between dawn and dusk during the flowering period. In addition, palynological studies were also conducted on the honey samples from the study area. The results showed that worker bees collected nectar and pollen from all three plants. Foraging densities varied from 67 per 1000 flowers in *K. venosa* to 401 per 1000 flowers in *M. kerstingii*. The average sugar content was 30.59% (*K. venosa*), 32.46 % (*M. kerstingii*), and 34.78% (*N. physlodes*). *M. kerstingii* produced high nectar; *N. physalodes* was found with high nectar and pollen content mean while *K. venosa* produced abundant nectar and a little amount of pollen. It was equally noticed that all honey samples contained traces of pollen grains from all the plants. A beekeeping calendar was also established for the three types of plants in the study area. Therefore, the protection of these plant species should be an important practice for the sustainability of beekeeping in Nyambaka.

Corresponding Author: Michelson A. Ela
Email: azooela@yahoo.fr

INTRODUCTION

The role of the honeybee (*Apis mellifera*) is well-known worldwide, and their functions are critical to ecosystem functioning and agriculture (Kasina et al., 2009; Hung et al., 2018; Saez et al., 2020). In addition to pollinating plant species, honeybees produce honey using nectar collected from flowers (Tyburce, 1996; Montoya et al., 2020; Sanz et al., 2005). People commonly collect pollen and honey from beehives, and also use other products from the hives for food and medicinal purposes (Molan, 2001). Management of bee colonies to produce honey and other products and to pollinate plants has been known and practiced since ancient times (Kritsky et al., 2017).

Beekeeping is a crucial activity supporting rural communities' economy (Ségeren et al., 1996; Reda et al., 2018). It creates various production and value chains (Qaiser et al., 2013). As the global demand for honeybee products continues to increase, the development of the beekeeping sector is vital (Dongock et al., 2017). In the Adamawa region of Cameroon, beekeeping is one of the most essential income-generating activities for smallholder farmers (Dongock et al., 2017). Beekeeping activities vary from manual collection methods to modernization with the introduction of modern tools, extraction, and packaging methods.

2012 Cameroon published a new National Biodiversity Strategy and Action Plan (NBSAP) based on the Convention on Biological Diversity (CBD). The policy describes the direction of reversing and halting the loss of biodiversity, which is important for the country's economic development and human life. It also defines the long-term vision for biodiversity as part of the National Vision for Growth and Employment 2035, including establishing a healthy relationship with biodiversity, maintaining the balance of ecosystems in line with development needs and human well-being, and ensuring effective participation of all stakeholders, including local communities. Therefore, the country continues striving to improve beekeeping production (DSCE, 2009). This includes the involvement of many non-governmental organizations working in agriculture and dedicated to training and supervising farmers in animal husbandry techniques and production and sales to support this project (e.g. INADES-Formation, APICAM, SAILD). In addition, beekeeping is included in the curriculum of most universities in Cameroon as a practical example of professionalization. There are many findings on the value and conservation of honeybee habitats and information on the use of technologies for large-scale honey production (e.g. Tchuenguem et al., 2007; Dongock et al., 2017; Beyssiri et al., 2017; Mbere et al., 2020) as well as several studies on plant-pollinator networks (e.g. Azo'o et al., 2020, 2021).

Despite the efforts of Cameroonian beekeeping stakeholders, the demand for the product continues to increase year to year (INADES, 2000), with Cameroon importing approximately 2 tons of honey each year (DSCE, 2009). Honey production in the country remains low, partly because the value of the plant for beekeeping is poorly known (Tchuenguem et al., 2010). It is generally known from the literature that honey and pollen production depend on plant diversity and attractiveness to bees (Leven et al., 2015). According to Dongock et al. (2017), the quantity and quality of hive products vary depending on the nature of the bee plants. The success of beekeeping depends on the presence and management of the local bee flora in terms of population density, nectar and pollen potential, and flowering time (El-Nebir and Talaad, 2013). Sustainable beekeeping in a given ecological region requires detailed knowledge of suitable plants growing near the apiary (Bakenga et al., 2000).

Grasses grown in agricultural fields, neglected open fields, vacant lots, and ornamental plants are important food sources for bees because they multiply quickly, and their seeds can be easily harvested and grown in the next cropping season. However, there is uncertainty about their agronomic characteristics, the time between flowering and fruiting, the quantity/quality of pollen and/or nectar production, and parameters related to honeybee flower-visiting activity (Tura et al., 2014). Such information can help in selecting, evaluating, growing and/or protecting particular plant species as bee food sources for honey production. This research project aimed to assess the beekeeping potential of three plant species in Nyambaka: *K. venosa* (Rubiaceae), *M. kertingii* (Chrysobalanaceae) and *N. physalodes* (Solanaceae). Specific goals for each plant species were: 1) The description of its characteristics, 2) The study of the activity of the foragers on the flowers, and 3) The evaluation of the apicultural status.

METHODOLOGY

Study site

The study was conducted in Nyambaka between June 2017 and March 2018 and in the same period of next year 2018/2019. Nyambaka is a village south of Ngaoundere, the Capital of the Adamawa Region of Cameroon (6-8°N; 11-15°E). The climate is divided into two seasons: the wet season (April-October) and the dry season (November-March). The Adamawa region belongs to the high-altitude savanna zone. The annual temperature is 22°C, the yearly average humidity is about 70%, and the mean annual rainfall is around 1,500 mm. This region is the first beekeeping region established in Cameroon (INADES, 2000).

Biological material

The selected plants for the study were located within a 1.5 km radius of the apiary (6°53’47’’N, 14°5’35’’E; 1136 m a.s.l.). The number of colonized Kenyan Top Bar hives in the area increased from 52 in June 2017 to 60 in March 2018 and 42 in June 2018 to 46 in 2019.

Methods

Plant species characteristics

The characteristics of the plants studied were related to five parameters such as the primary color of the flowers, the total number of flowers, the number of individuals of each plant species, the duration of blossoming (the time interval between the opening of the first flower and the closing of the last flower), and the flowering period in the year. The nectar concentration (sugar) was also evaluated using a refractometer (0-90% Brix). Five nectar harvesters were captured and anesthetized in a box containing cotton soaked in chloroform. Nectar was obtained from the bees by exerting pressure with the thumb and the forefinger on the captured bee abdomen and the sugar concentration was measured in g/100 dry matter (Tchuenguem et al., 2004).

Flower-visiting parameters of the honeybees

Bees’ flower-visiting parameters were estimated for each studied plant. Data collection was done for two days and chosen randomly in a week. Three time slots were dedicated for observations: 07:00-11:00, 11:00-03:00, and 03:00-06:00. For each of the three plants; four activity parameters were recorded: the daily rhythm of activity of the worker bee following the daily time frames, the duration of a floral visit by the worker bee to harvest floral products, the ratio between nectar and pollen collection visits, and the foragers’ abundance per flower based on the procedure of Tchuenguem et al. (2004).

Pollen spectrum

The pollen spectrum was studied to determine the pollen profile from the pollen baskets on the hind legs of honeybees. Five pollen foragers were caught on the flowers of each plant species and anesthetized. In the laboratory, the pollen pellets were removed from the corbiculae for further microscopic analysis.

Palynological analysis of honey samples

To know whether the plants studied contributed to honey production, the pollen from each studied species was sought from the honey collected from the study site. Honey samples were collected from six experimental Kenyan Top Bar Hives for the pollen analysis. The collected honey samples were stored in glass bottles at the ambient temperature.

The analysis was carried out in the LANAVET (National Veterinary Laboratory) of Yaoundé, Cameroon, according to the acetyl separation method of Louveaux et al. (1978). The conceived slides were properly screened using a mic (Weiss primo star, goal 40, eyepiece 10). For each honey sample, a count was made on each of the three slides by examination of the different fields of the microscope. Drawings or pictures of various morphological types of pollen grains found in each sample were made to facilitate pollen identification. In addition, the atlas of pollen belonging to different botanical species was used to compare and confirm the three pollen types.

Statistical analysis

STATGRAPHICS plus 8.0 program was used to perform descriptive statistics on the data. Multiple comparisons of means were made using Tuckey Kramer’s one-way Analysis of Variance (ANOVA) and post-hoc test (HSD), P value sets at 0.05. Student’s t test was used to compare the means of two samples. The average value (*mo*) was followed by the standard deviation (*sd*).

RESULTS

Botanical characteristics of the plants

Table 1 describes some characteristics of the studied plants. *M. kerstingii*, *K. venosa* and *N. physalodes* are trees, shrubs and herbs respectively growing along roadsides in forests and Savannas. The flowers of *K. venosa* and *M. kerstingii* are white, while those of *N. physalodes* are purple. The total number of stands was 178 for *M. kerstingii*, 453 for *K. venosa*, and 6170 for *N. physalodes*. The blooming period of *M. kerstingii* was about 157 days, and 181 and 186 days for *N. physalodes* and *K. venosa* respectively.

Table 2 shows the blossoming periods of the studied plant species. *M. kerstingii* blooms from November to March, with a peak in January and February, while *K. venosa* and *N. physalodes* bloom from June to November, with a peak in August. The mean number of flowers per stand varied from 76 ± 12 in *N. physalodes*, 374 ± 143 in *K. venosa*, and 12326 ± 365 in *M. kerstingii* (Table 3). Considering the size of each studied speculation in the area, the deduced floral mass per flowering period varied from about 169,422 flowers in *K. venosa* to 468,920 in *N. physalodes* and 2,194,028 in *M. kerstingii*; The potential of each of the three plant species to produce quantity and quality floral mass in a year contributes enormously to the sustainability of beekeeping practice in Nyambaka.

Table 1. Some botanical characteristics of different plant species studied.

Scientific name and status	Flowering duration	Flower colors	Individuals
Keetia venosa (sb)	186 days	White	453
Maranthes kerstingii (te)	157 days	White	178
Nicandra physalodes (gr)	181 days	Purplish	6170

te: tree; sb: shrub; gr: grass

Table 2. Variation of the flowering intensity following the time.

	Months									
	Jn	Jy	Au	Sp	Oc	No	De	Je	Fe	Ms
K. venosa	*	***	****	***	**	*				
M. kerstingii						*	**	****	****	*
N. physalodes	*	***	****	***	**	*				

Jn: June; **Jy**: July; **Au**: August; **Sp**: September; **Oc**: October; **No**: November; **De**: December; **Je**: January; **Fe**: February; **Ms**: March; *: ≤ 100 flowers; **: > 100 and ≤500 flowers; ***: > 500 and ≤1000 flowers; ****: > 1000 flowers

Table 3. Mean number of flowers per plant during blooming period.

Plant species	2017 – 2018				2018 – 2019			
	Number of flowers				Number of flowers			
	n	*mo ± sd*	*mi*	*ma*	*n*	*mo ± sd*	*mi*	*Ma*
K. venosa	54	374 ± 243	17	1054	43	242 ± 71	6	1054
M. kerstingii	38	12326 ± 265	24	26742	32	10167 ± 543	14	32407
N. physalodes	82	76 ± 12	2	764	97	94 ± 17	2	825

n = size of the sample; *mi* = minimum; *ma* = maximum; *mo* = average; *sd* = standard deviation, *mi* = minimum; *ma* = maximum

Table 4 shows the average sugar concentration in the nectar in each studied plant. The mean value for *K. venosa* was 33.96% (n = 50; sd = 1.73) in 2017/2018 and 34.21% (n = 50; sd = 2.40) in 2018/2019, showed no difference between the two years (t = 0.28, df = 77, P > 0.05). The value for *M. kerstingii* was 32.46 % (n = 50; sd = 3.44) in 2017/2018 and 30.59 % (n = 50; sd = 4.78) in 2018/2019, showed very slight difference between the years (t =2.70, df = 143, P < 0.01). Finally, for *N. Physalodes*, the 2017/2018 value was 34.27% (n = 50; sd = 4.47) and the 2018/2019 value was 34.78% (n = 50; sd = 4.17), with no difference between the different years (t = 0.50; df = 94, P > 0.05). This measure was different between our sites in 2017/2018 (F = 14.10; df = 2, 147; P < 0.05) and 2018/2019 (F =17.50; df = 2, 147; < 0.00). In general, the total sugar concentration varies from plant to plant, and the nectar concentration on the same plant may vary from year to year.

Floral activity of foragers

Rhythm of honeybee on studied plants

During the flowering period, worker bees visited *K. venosa*, *M. kerstingii* and *N. physalodes* every day. In figure 1, it can be seen that the food collection activity of bees on *N. physalodes* flowers reached its peak between 12:00-15:00 daily intervals and gradually decreased as the flowers begin to wither. However, foraging activities on *K. venosa* and *M. kerstingii* flowers occurred between 07:00-11:00 in the morning and 15:00-18:00 in the afternoon with a decreased in activities around noon.

Frequency and intensity of honeybee flower-visits for food gathering

Table 5 lists food resources collected by *A. mellifera* workers from the flowers of different plant species and the collection intensities and frequencies. *K. venosa* flowers were less visited for its pollen, while its sweet nectar was very attractive to honeybee visitors. *M. kerstingii* flowers were frequently visited by honeybee foragers, particularly for their nectar. *N. physalodes* flowers were commonly visited by *A. mellifera* at equal frequency for pollen and nectar harvesting. In general, honeybee activities varied from plant to plant, and the floral product required for a given plant species also varied. Figure 2 shows honeybee workers foraging on flowers of the three plant species studied.

Table 4. Average sugar concentration in the nectar of studied plants.

Plant species	Sugar concentration (%)							
	2017-2018				2018-2019			
	n	*mo ± sd*	*mi*	*Ma*	*n*	*mo ± sd*	*Mi*	*Ma*
K. venosa	50	33.26 ± 1.73	27	37	41	34.40 ± 2.40	37	27
M. kerstingii	72	32.46 ± 3.44	26	43	73	30.59 ± 4.78	22	39
N. physalodes	46	34.27 ± 4.47	27	41	50	34.78 ± 4.17	29	45

n: size of the sample; *mo*: average; *mi*: minimum; *ma*: maximum

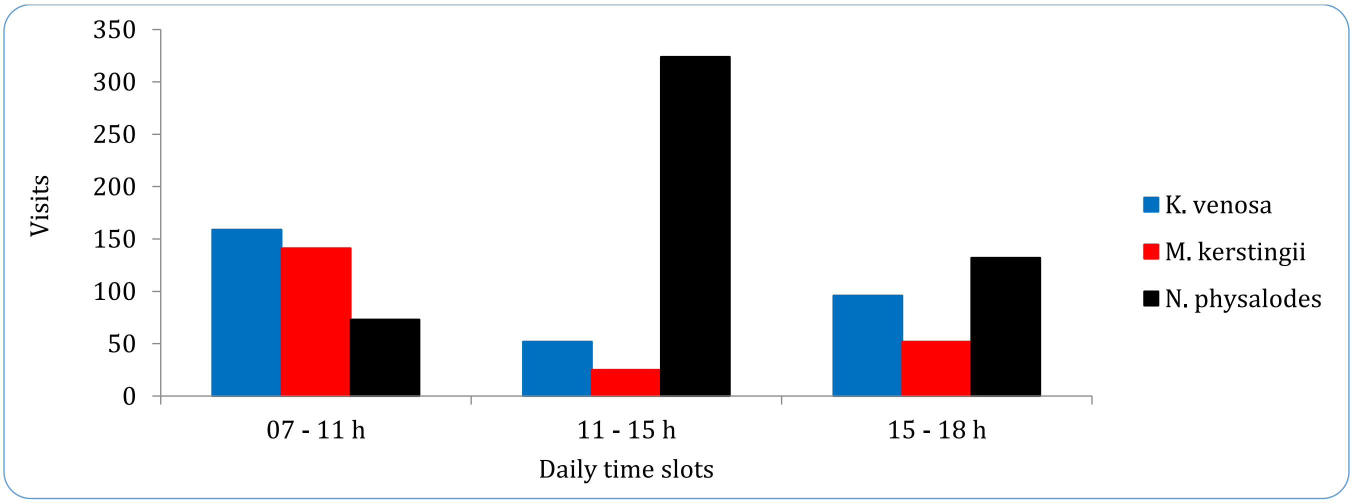


Figure 1. Daily distribution of *Apis mellifera* visits on the flowers of plant species studied.

Table 5. Floral resources collected by foragers based on months and their availability.

Plant species	Jn	Jy	Au	Sp	Oc	No	De	Je	Fe	Ms	T	%Nc	%Pn
K. venosa	Nc^2	Nc^4Pn^2	Nc^4Pn^2	Nc^3Pn^1	Nc^1						76	100%	31.57%
M. kerstingii							Nc^1	Nc^4	Nc^4	Nc^1	56	100%	0%
N. physalodes	Nc^1Pn^2	Nc^3Pn^3	Nc^4Pn^4	Nc^3Pn^2	Nc^2Pn^2	Nc^1Pn^1					96	100%	100%

T: Total observation days; **%Nc**: Daily proportion for nectar foraging; **%Pn**: Daily proportion for pollen collection; **Nc**: Nectar; **Pn**: Pollen; Superscripts 1 (very low), 2 (low), 3 (high), 4(very high) are simulations of the food collection intensity by honeybees

Worker bee density

The number of worker bees collecting floral rewards simultaneously from same flower was 1 in *K. venosa* and *N. physalodes*, and 1-2 in *M. kerstingii*. The corresponding abundance/1000 flowers were 74 (n = 290; *sd* = 37; *ma* = 253) for *K. venosa*, 331 (*n* = 151; *sd* = 264; ma = 804) for *M. kerstingii*, and 168 (*n* = 216; *sd* =152; *ma* = 562) for *N. physalodes* in 2017/2018. In 2018/2019, the results were 67 (*n* = 239; *sd* = 30; *ma* = 216) for *K. venosa,* 401 (*n* = 132; *sd* = 269; ma =851) for *M. kerstingii*, and 149 (*n* = 226; *sd* = 141; *m* = 505) for *N. physalodes*. In all, the best foraging density values of *A. mellifera* corresponded to the month where each plant species produced important flower biomass (July-August) for *K. venosa*, January-February for *M. kerstingii*, and July-September for *N. physalodes* (Table 6).

Figure 2. Honeybee foraging activity on *Keetia venosa* (a), *Nicandra physalodes* (b), and *Maranthes kerstingii* (c).

Table 6. Mean abundance values of foragers/1000 flowers per plant and months.

Plant species	Jn	Jy	Au	Sp	Oc	No	De	Je	Fe	Ms
K. venosa	16	292	103	24	11					
M. kerstingii						18	68	732	804	36
N. physalodes	16	58	358	563	13	2				

Jn: June; Jy: July; Au: August; Sp: September; Oc: October; No: November; De: December; Je: January; Fe: February; Ms: March

Average flower-visit time following the floral product harvested

Results reported in Table 7 showed that, in 2017/2018, the average duration of a visit for nectar harvesting on *K. venosa*, *M. kerstingii*, and *N. physalodes* by *A. mellifera* were 3.51 sec (n = 200; sd = 1.78), 8.04 sec (n = 200; sd = 8.80) and 2.13 sec (n = 200; sd = 0.64) respectively; the corresponding values in 2018/2019 were 3.35 sec (n = 200; sd = 1.43), 7.34 sec (n = 200; sd = 7.97) and 2.40 sec (n = 200; sd = 0.84). Pollen grains were collected from only two species. The average duration of a visit for grains collection on *K. venosa* and *N. physalodes* in 2017/2018 was 3.02 sec (n = 100; sd = 1.40) and 10.62 sec (n = 100; sd = 7.14), respectively, and the corresponding values in 2018/2019 were 3.03 sec (n = 100; sd = 1.36) and 10.23 sec (n = 100; sd = 7.06). Generally, the duration of a forager's visit varies according to the floral resources sought. A significant difference was observed comparing pollen and nectar collection of *N. physalodes* (t = 19.83; df = 298; P < 0.001; 2017/2018; t = 16.20; df = 298; P < 0.001; 2018/2019), and significant differences in nectar collection when comparing among the plants studied (F = 32.80; df_1 = 2; df_2 = 597; P < 0.05; 2017/2018; F = 67.75; df_1 = 2; df_2 = 597; P < 0.05; 2018/2019). Equally significant differences were observed for the duration of pollen harvesting in *K. venosa* and *N. physalodes* (t = 8.33; df = 198; P < 0.001; 2017/2018; t = 7.44; df = 198; P < 0.001; 2018/2019).

Table 7. Average time of worker visits following floral products explored per plant species.

Plant species	2017-2018				2018-2019			
	Average flower-visit time (seconds)				Average flower-visit time (seconds)			
	n	*mo ± sd*	*mi*	*ma*	*n*	*mo ± sd*	*mi*	*ma*
K. venosa (Nc)	200	3.51 ± 1.78	2	11	200	3.35 ± 1.43	1	7
K. venosa (Pn)	100	3.02 ± 1.40	1	7	100	3.03 ± 1.36	1	6
M. kerstingii (Nc)	200	8.04± 8.80	1	42	200	7.34 ± 7.97	1	40
N. physalodes (Nc)	200	2.13 ± 0.69	1	7	200	2.22 ± 0.75	1	8
N. physalodes (Pn)	100	10.62 ± 7.14	1	22	100	10.28 ± 7.06	2	25

n: size of the sample; *mo*: average; *mi*: minimum; *ma*: maximum; Nc: Nectar harvesting; Pn: Collection of pollen

Pollen spectrum of loads from pollen baskets

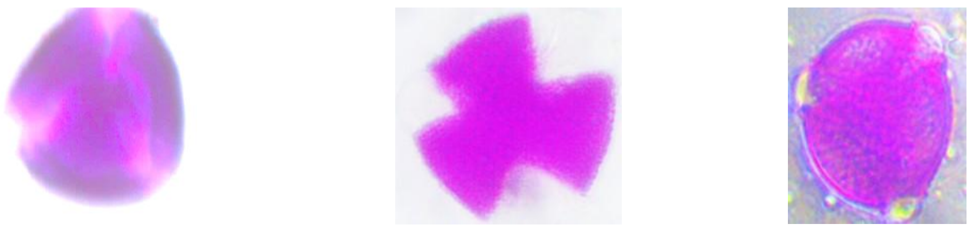
Table 8 shows the pollen grain spectrum from pollen baskets of individual bees captured on the flowers examined. The average number of pollen grains collected by honeybees from *K. venosa* flowers was 2107 ± 214. The vast majority of the pollen grains examined

(99.48%) originated from the Rubiaceae, while only a few (0.52%) were from the neighboring plant species *Allophilus africanus* and *Ageratum conyzoides*. Similarly, only 0.69% of pollen grains were collected on *Mimosa pudica* and *Tithonia diversifolia* flowers from the 9667 pellets from foragers captured on *N. physalodes* flowers. Figure 3 shows pollen grain pictures of *M. kerstingii* (a), *K. venosa* (b), and *N. physalodes* (c).

Table 8. Pollen spectrum of loads from baskets of honeybee foragers.

	Number of pollen grains				
Plant species	Total	Plant studied	Other plants	%Other pollen	Other plant
K. venosa	2107	2096	11	0.52	Aa, Mp
N. physalodes	9667	9326	65	0.69	Td, Ac

Aa: *Allophilus africanus*; Ac: *Ageratum conyzoides ;* Mp: *Mimosa pudica* ; Td: *Tithonia diversifolia*.



Maranthes kerstingii (a) *Keetia venosa* (b) *Nicandra physalodes* (c)

Figure 3. Photograph of pollen grains from plant species studied.

Figure 3 shows photographs of pollen grains from plant species studied.

Pollen analysis from honey samples

The pollen analysis of honey samples collected from hives in the study area presented in Table 9 showed that: a) The amount of pollen in the honey samples No.1 to No.6 were 23040, 33307, 26605, 28282, 19437, and 27343 respectively; b) All the samples were multiflora; c) *K. venosa* pollen was found in two honey samples (No.1 and No. 4), accounted for 1.68% and 1.36% respectively; d) The sample No.1, 2 and 3 with pollen grains of *M. kerstingii*, accounted for 1.51%, 4.36%, and 0.14%; e) The pollen of *N. physalodes* was identified in two samples, No.1(1.96%) and No.2 (0.64%). These three plants together were the main source of sugar and proteins for honey production in the study area.

Bee plant status

During the blossoming season, it was noticed that honeybees work on the flowers differently. The flowers here were numerous thus the number of workers visiting flowers of each plant was higher and nectar harvesting was easier due to the high sugar concentration, availability and accessibility of the food resources. In the dry season, individual plants of *M. kerstingii* produced huge quantity of flowers, while in the rainy season, *K. venosa* and *N. physalodes* also provided abundant food stock honeybees. Based on the high frequency, honeybee foragers collected enough nectar and/or pollen from the visited flowers. The three plant species were classified as follows: 1) A higher nectar and pollen provided by grass species for honeybees (*N. physalodes*), 2) A tree species with a very pleasant nectar which was harvested abundantly by *A. mellifera* (*M. kerstingii*), and 3) A shrub which provided much sugar and little pollen grains (*K. venosa*) to honeybees. The pollen identification in honey samples indicated that these plants are suitable for the sustainable development of apiculture in the study area namely Nyambaka.

DISCUSSION

Maranthes kerstingii, *K. venosa* and *N. physalodes* are three wild plant species which grow in the vicinity of apiaries in Nyambaka spontaneously. The relationship between honeybees and these flowers had not been documented in Cameroon. The two years of observations in Nyambaka showed that *A. mellifera* was the most common insect feeding on the flowers of these studied plant species. We can therefore consider these plant species as being among the main food resources for improvement of beekeeping in the locality. Furthermore, these results allow us to enrich our pre-existing database with three new species that have high beekeeping potential for the sustainability of honey production in Cameroon. The apiculture status of the plant species studied was already known in some other countries such as Benin (Yédomonhan et al., 2009), Nepal (Sanjaya and Gopal, 2001), Brazil (Mouga et al., 2015) without much details as in this case.

Table 9. Proportion of pollen grains identified in six honey samples in the laboratory.

Species plants	Sample 1		Sample 2		Sample 3		Sample 4		Sample 5		Sample 6	
	n	F (%)	n	F (%)	n	F (%)	n	F (%)	n	F (%)	n	F (%)
Acanthospermum hispidium	-	-	2451	7.36	-	-	-	-	1251	6.44	-	-
Allophylus africanus	386	1.68	-	-	2140	8.04	588	2.07	254	1.31	-	-
Bidens steppia	-	-	386	1.16	386	1.45	-	-	-	-	386	1.41
Hymenocardi acida	2363	10.26	1359	0.86	1502	5.65	548	1.94	-	-	9395	34.36
Jatropha curcas	-	-	421	4.08	-	-	-	-	174	0.90	-	-
Keetia venosa	386	1.68	-	-	-	-	386	1.36	-	-	-	-
Lannea schimperi	-	-	1006	1.26	158	0.59					3451	12.62
Leucaena leucocephala	245	1.06	254	3.02	107	0.40	-	-	-	-	-	-
Maranthes kerstingii	347	1.51	355	4.36	38	0.14	-	-	-	-	-	-
Mimosa invisa	395	1.71	165	1.07	105	0.39	-	-			-	-
Mimosa pudica	-	-	-	-	457	1.72	1251	4.42	2316	11.92	-	-
Nicandra physalodes	452	1.96	214	0.64	-	-	-	-	-	-	-	-
Persea americana	1508	6.54	2546	7.64	338	1.27	1452	5.13	-	-	586	214
Pittosporum viridiflorum	-	-	1452	4.36	-	-	5421	19.17	1254	6.45		
Psidium guajava	-	-	-	-	5874	22.08	6547	23.15	241	1.24	7541	27.58
Psorospermum febrifugum	1909	8.29	1245	3.74	212	0.80	-	-	1245	6.41	234	0.86
Psychotria mahonii	-	-	-	-	158	0.59	745	2.63	-	-	-	-
Zea mays	-	-	1214	3.64	-	-	-	-	1254	6.45	-	-
Others plants (37 species)	15049	65.31	20239	60.77	15130	56.87	11344	40.11	11448	58.90	5750	21.03
Total	23040	100	33307	100	26605	100	28282	100	19437	100	27343	100

n = number of pollen grains; F = proportion of pollen grains

The nectar concentration of the three plant species is greater than 30%, hence the high attractiveness of honeybees to these plant species. Proctor et al. (1996) supported that, the sugar content in nectar varies very strongly within plant species (15% and 75%) which is the case with our results which fall within this range. Therefore, the loyalty or faithfulness of honeybees to the flowers of the experienced plants is partly explained by the availability, the accessibility, and above all, the richness of their nectars in sugars. The higher the sugar content of the nectar, the more energy it provides to the bee in the hive (Tchuenguem et al., 2010). According to Philippe (1991), worker bees would not enable their colonies to keep more working energy if the sugar in the nectar foraged is less than 20%. Given this minimal value, foragers will allow their congeners to gain more energy while collecting food resources from *M. kerstingii*, *K. venosa* and *N. physalodes*. In fact, the sweeter the nectar, the less energy bees need to convert it into honey (Tyburce, 1996). In addition, the faithfulness of *A. mellifera* foragers on the flowers visited may be explained by the scarcity of foreigner pollen grains in the pellets of their corbiculae (Tchuenguem et al., 2007).

Across the study, honeybees were active at all times of day when collecting floral rewards on flowers of the plant species studied. Their daily schedules, however, vary depending upon the availability and profitability of rewards. Peak in honeybee activity noted on each speculation may reflect the maximal availability of desired floral food (Moore, 2001).

The flowering periods varied according to the plant species. Some plants bloom once a year, while others bloom only at certain times. The occurrence of plants with different flowering regimes in an area may influence the occurrence of local bee colonies (Njau *et al*., 2009). Therefore, the study of bee plants in a given area, including their richness, distribution, and floristic knowledge, is very important for obtaining quantitative and qualitative honey yield and for fighting against honey shortage in a given area (Tchuenguem et al., 2010). Thus, the supply of honeybee colonies by beekeepers of the Adamawa region of Cameroon with floral products from *K. venosa*, *M. kerstingii*, and *N. physalodes* is already possible because the apicultural calendar of these studied plant species was very precisely determined throughout the present study.

Palynological analysis contributes to honey differentiation (Prodolliet and Hischenhuber, 1998). The characteristics of poly-floral honey were confirmed by counting pollen grains in the six samples of examined honey. Finding pollen grains in honey indicates the specific plants that bees forage on in a given area (Joshi et al., 1998). The variability of pollen grains in honey varies with areas and availability of bee plants identified here (Song et al., 2014). Therefore, pollen grain studies in honey provide an important information about bee resources. Palynological study of different honey samples collected showed that the bee flora in the study area is very diverse and requires further research and protection.

CONCLUSION

Cameroon' beekeeping potential is high. Efforts to train beekeepers, strengthen their skills and improve their understanding of the apicultural environment are ongoing. The present work was a contribution to the knowledge of the diversity of bee plants in Adamawa, Cameroun, in a context of sustainable and efficient beekeeping practice. *K. venosa*, *M. kerstingii*, and *N. physalodes* appeared as three plant species known to be important food suppliers to honeybees in the study area. All these plant species contributed to the feeding and strengthening of the honeybee colonies since the pollen grains were found in honey samples of the study area. For recommendations: (a) Beekeepers are encourage to place their beehives where these three plant species grow; (b) Beekeepers are also encourage to protect or domesticate each of these three studied plant species around their apiaries; (c) The government should encourage indigenous populations to better preserve nature and the bees.

ACKNOWLEDGEMENTS

Authors would like to thank the anonymous reviewers for their comments and corrections which helped us to improve on this work.

REFERENCES

Azo'o, E.M., W.B. Bissou and F.F.N. Tchuenguem. 2020. Comparing the foraging behavior and pollination efficiency of *Apis mellifera* with *Xylocopa olivacea* (Apidae: Hymenoptera) on *Citrullus lanatus* flowers. Journal of Applied Horticulture, 22 (1): 18-23.

Azo'o, E.M., A.M. Tchopwe, H. Sanda, C. Firitawada, B.B. Aïne, T.M.M. Njoya, Tchobsala and F.F.N. Tchuenguem. 2021. Impact of floral activities of bee species (Hymenoptera: Apidae) on seed yield and germinability of *Calotropis procera* (Asclepiadaceae) in northern Cameroon. Belgian Journal of Entomology, 121: 1–24.

Bakenga, M., M. Bahati and K. Balagizi. 2000. Inventaire des plantes mellifères du Bukavu et ses environs

(Sud-Kivu, Est de la République Démocratique du Congo). Tropicultura, 18(2): 89-93.

Beysirri, D., F. Dongmo, I.D. Soudi, A.H. Mahamat, K. Ngo Ngimout, D.S. Sonkeng and F.F.N. Tchuenguem. 2024. Antidiabetic and antioxydant effect of ethanolic extract of propolis from Meiganga (Cameroon) on type 2 diabetes in rats. International Journal of Diabetes and Endocrinology, 9(1): 1-12.

Dongock, N.D., E. Zra and F.F.N Tchuenguem. 2017. Bee plant potentials and characteristics in the Ngaoundal subdivision, Adamawa-Cameroon. Agricultural Science Research Journal, 7(9): 285-296.

DSCE. 2009. Document de Stratégie pour la Croissance et l'Emploi. 1st ed., MINEPAT, Yaoundé, 112 p.

Edwards, S. 1976. Some wild flowering plants of Ethiopia. Addis Ababa University press. Addis Ababa, Ethiopia, 76 p.

El-Nebir, M.A. and D.A.M. Talaat. 2013. Identification of botanical origin and potential importance of vegetation types for honey production in the Sudan. Journal of Natural Resources and Environmental Studies, 1(2): 13-18.

Hung, K.L.J., J.M. Kingston, M. Albrecht, D.A. Holway and J.R. Kohn. 2018. The worldwide importance of honeybees as pollinators in natural habitats. Proceedings of the Royal Society B Biological Sciences, 285: 20172140-20172147.

INADES. 2000. Rapport des ateliers avec les Apiculteurs de l'Adamaoua. INADES (eds), INADES Formation, Maroua, 29 p.

Joshi, M.A, K. Lakshmi and M.C. Suryanarayana. 1998. Melissopalynological investigations on *Apis* and *Trigona* honeys collected in and around Pune, Maharashtra. Indian Bee Journal, 60: 90-98.

Kasina, J.M., J. Mburu, M. Kraemer and K. Holm-Mueller. 2009. Economic benefit of crop pollination by bees: a case of Kakamega small-holder farming in werstern Kenya. Journal of Economic Entomology, 102 (2): 467-473.

Kritsky, G. 2017. Beekeeping from antiquity through the middle ages. Anual Review of Entomology, 62(1): 249-264.

Leven, L., V.W.J. Mutsear, P. Ségeren and P. Velthuis. 2005. Beekeeping in the tropics. 6th ed., Agromissia foundation and CTA, Wageningen, 87 p.

Louveaux, J., A. Maurizio and G. Vorwohl. 1978. Methods in melissopalynology. Bee World, 59 (4): 139-157.

Mbere, N., M.E. Azo'o, Tchobsala and F.F.N. Tchuenguem. 2020. Floral activity of *Apis mellifera* (Hymenoptera: Apidae) on *Bidens steppia* (Asteraceae), *Cordia africana* (Boraginaceae), *Pittosporum viridiflorum* (Pittosporaceae) and *Psychotria mahonii* (Rubiaceae) in Nyambaka (Adamawa, Cameroon). African Journal of Agricultural Research, 16 (9): 1278-1288.

Molan, P.C. 2001. Why honey is effective as a medicine. 2 - The scientific explanation of its effects. Bee World, 82 (1): 22-40.

Montoya, D., S. Gaba, C., Manzacourt, V. Bretagnolle and M. Loreau. 2020. Reconciling biodiversity conservation, food production and farmers' demand in agriculture landscapes. Ecological Modelling, 416: 108889-108909.

Moore, D. 2001. Honey bee circadian clocks: behavioral control from individual workers to whole-colony rhythms. Journal of Insect Physiology, 47: 843-857.

Mouga, D.M.D.S., V. Feretti, J.C. De Sena, M. Warkentin, A.K.G. Dos Santos and C.L. Ribeiro. 2015. Ornamental bee plants as foraging resources for urban bees in Southern Brazil. Agricultural Sciences, 6: 365-381.

Njau, M.A., P.M. Mpuya and F.A. Mturi. 2009. Apiculture potential in protected areas: the case of Udzungwa Mountains National Park, Tanzania. International Journal of Biodiversity Science and Management, 5(2): 95-101.

Philippe, J.M. 1991. La pollinisation par les abeilles : pose des colonies dans les cultures en floraison en vue d'accroître les rendements des productions végétales. EDISUD, 179 p. La Calade, Aix-en-Provence, 178 p.

Proctor, M., P. Yeo and A. Lack. 1996. The natural history of pollination. Corbet S. A., Walters S. M., Richard W., Streeter D. et Ratcliffe D. A. (ed.), Harper Collins New Naturalist, London, 462 p.

Prodolliet, J. and C. Hischenhuber. 1998. Food authentification by carbohydrate chromatography. Zeitschrift für Lebensmitteluntersuchung und-Forscung A, 207: 1-12.

Qaiser, T., M. Ali, S. Taj and N. Akmal. 2013. Impact assessment of beekeeping in sustainable rural livelihood. Journal of Social Sciences, 2: 82–90.

Reda, G.K., S. Girmay and B. Gebremichael. 2018. Beekeeping practice and honey production potentiel in Afar Regional State, Ethiopia. Acta Universitatis Sapientiae Agriculture and Environment, 10: 66-82.

Saez, A., M.A. Aizen, S. Medici, M. Viel, E. Villalobos, and P. Negri. 2020. Bees increase crop yield in an alleged pollinator-independent almond variety. Scientific Reports, 10: 3177-3183.

Sanjaya, B. and P.S. Gopal. 2001. Honeybee Flora at Kabre, Dolakha District. Nepal Agricultural Research Journal, 4 (5): 18-25.

Sanz M.L., M. Gonzales, C. de Lorenzo, J. Sanz and I. Martinez-Castro. 2005. A contribution to the differentiation between nectar honey and honeydew honey. Food Chemistry, 91(2) : 313-317.

Ségeren, P., Mulder, Beetsma and R. Sommeijer. 1996. Apiculture sous les tropiques. 5ème ed., 88 p. Agromisa, Wageningen, 88 p.

Song, X.Y., Y.F. Yang and W.D. Yang. 2012. Pollen analysis of natural honeys from the central region of Shanxi, North China. Plos One, 7 (11): 1-19.

Tchuenguem, F.F.N., J. Messi, D. Brückner, B. Bouba, G. Mbofung and H.J. Hentchoya. 2004. Foraging and pollination behavior of the African honey bee (*Apis mellifera adansonii*) on *Callistemon rigidus* flowers at Ngaoundéré (Cameroon). Journal of Cameroon Academic Sciences, 4: 133-140.

Tchuenguem, F.F.N., D. Djonwangwe, J. Messi and D. Brückner. 2007. Exploitation of *Dichrostachys cinerea*, *Vitellaria paradoxa*, *Persea americana* and *Securidaca longepedonculata* flowers by *Apis mellifera adansonii* Latreille (Hymenoptera: Apidae) at Dang (Ngaoundéré, Cameroon). International Journal of Tropical Insect Sciences, 28 (4): 225-233.

Tchuenguem, F.F.N., T.S. Fameni, M.A. Pharaon, J. Messi and D. Brückner. 2010. Foraging behaviour of *Apis mellifera adansonii* (Hymenoptera: Apidae) on *Combretum nigricans, Eryhrina sigmoidea, Lannea kerstingii* and *Vernonia amygdalina* flowers at Dang (Ngaoundéré, Cameroon). International Journal of Tropical Insect Sciences, 30 (1): 40-47.

Tura, B.K., W.H. Kibebew and A.M. Admassu. 2014. Screening of potential herbaceous honey plants for beekeeping development. Agriculture, Forestry, and Fisheries, 3(5): 386-391.

Tyburce, B. 1996. Transformation des sucres par l'abeille, du nectar au miel. L'abeille de France, 81: 211-215.

Yédomonhan, H., M.G. Tossou, A. Akoègninou, B.B. Demènou and D. Traoré. 2009. Diversité des plantes mellifères de la zone soudano-guinéenne: cas de l'arrondissement de Manigri (Centre-Ouest du Bénin). International Journal of Biological and Chemical Sciences, 3 (2): 55-366.

Publisher's note: EScience Press remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.