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Quantification of bee forage value of selected tree species of Kodagu district, Karnataka, India

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Abstract
The bee forage valuewas estimated in *Cinnamomum zeylanicum, Perseaamericana, Millettia pinnata, Gliricidiasepium,* and *Santalum album* in Kodagu during 2019- 20. The techniques of the capillary tube, nectar washing and crop capacity were used for nectar estimation. Pollen production was estimated by relating the number of flowers visited by a forager per trip and the mean weight of pollen carried by them. A significantly highest (3µl) and lowest (0.52 µl) volume of nectar per flower was produced in *S. album* and *C. zeylanicum,* respectively. The nectar volumes in *S. album* (45,975 µl) enticed 1688 nectar foragers while *P. americana* (2042.25 µl) sufficed 75 nectar foragers. The amount of pollen per flower (3.92 mg) and per tree (20,254.6mg) was significantly highest in *G. sepium*. *Cinnamomumzeylanicum* produced lowest quantity of pollen per flower (0.33 mg) and per tree (6718.9 mg) basis it was in *P. americana.*

Keywords: Bee forage value, nectar, pollen, crop capacity

1. Introduction
Honeybees play a vital role for the preservation of ecological balance, improving the diversity of ecosystems and in improving the economy for mankind. Flowers are the mainstay of the bee's life. The ever increasing demand for pollen and nectar in bee colonies compel the worker bees to involve in the collection of pollen and nectar [1]. On an average, an *Apismellifera* L. colony requires about 120-125kg of nectar and 20–30 kg of pollen grains per annum [2]. Pollen collection in the colony is regulated according to the colony's needs. Normally each colony maintains about 1 kg of stored pollen. Due to factors like soil type, climatic conditions and the habitat of the vegetation, the blooming period of the plants contributing nectar and pollen to honeybees may vary in times of the year. Nectar collection is regulated according to floral nectar availability, with great daily and seasonal fluctuations [3]. The bee forage value estimation will thus be useful to know the potentiality of the forage plants so that such plants can be augmented in resource dearth areas to improve the honey yield and conserve the status of economically important melliferous plants. Therefore, it was felt necessary to take up studies on bee forage plants to estimate the pollen and nectar yielding potentiality of important bee forage trees in the ecosystem of Kodagu district, which is a part of Western Ghats ecosystem.

2. Materials and Methods
The assessment of forage value in terms of quantity of pollen and nectar produced by the trees was carried out on five bee forage tree species, namely *Cinnamomum zeylanicum, Santalum album, Perseaamericana, Millettia pinnata, Gliricidiasepium,* at the College of Forestry campus, Ponnampet during their peak flowering period and the potentiality of the species in producing pollen and nectar was estimated.

2.1 Nectar estimation
The quantity of nectar produced by the trees was assessed by capillary tube technique, and the number of nectar foragers enticed by the tree was estimated by the crop capacity technique.

2.1.1 Capillary tube technique
A known number of unopened flowers were bagged (to prevent the visit of the nectar collectors).

Once the flowers opened, they were collected and brought to the laboratory for nectar estimation. For the flowers of *M. pinnata*,*G. sepium*, *C. zeylanicum*, the basal portion was cut to expose the floral nectaries, and the nectar in them was measured by using a graduated capillary tube. In flowers that were small and had viscous nectar (*P. americana*, *S. album*) the nectar washing technique was followed in which the floral nectaries were cut and centrifuged (portable centrifuge) in vials with a known amount of water (10µl) [4]. The increase in the volume of water was measured to estimate the mean value of the quantity of nectar per flower. Further, based on the number of flowers per square meter of the canopy area and the total canopy area of the trees, the total quantity of nectar available in the tree was estimated. The bagged flowers (25 numbers in each sampling) were collected for nectar estimation thrice a day (8-10 hr, 12-14 hr and 15 – 17 hr) consecutively for three days during the peak flowering periods (Plate 1 and 2).

2.1.2 Crop capacity technique

The crop capacity of the nectar forager was estimated as follows. A known quantity of sugar syrup (200 µl) placed over a glass slide was provided to the visiting *Apiscerana indica* Fab. nectar foragers in the feeding station established at a distance of 500 meters from the apiary. The foragers habituated to visit the feeding station came over the glass slides and collected the syrup from the surface of the glass slides. For every slide, only five numbers of foragers were allowed to collect the syrup. Then the quantity of leftover syrup on the slide was measured with the help of a graduated capillary tube. The difference between the sugar syrup offered to the bees (5 Nos) and the leftover amount was worked out. Based on the total quantity of syrup engorged by these five foragers; the amount of syrup engorged by a single bee was worked out and taken as the crop capacity or honey stomach capacity of the bees (Plate 3).

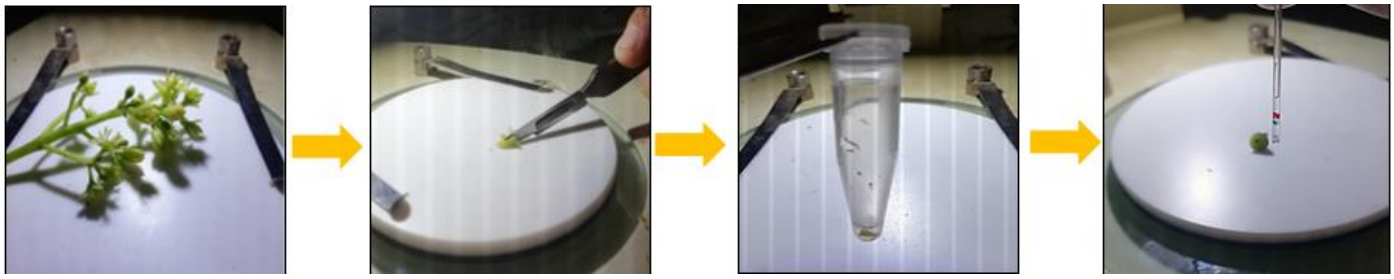
By taking into account the crop capacity and the average number of flowers visited by a bee in a single trip, the quantity of nectar available per flower was worked out. The same was extrapolated for the entire tree, considering the total canopy area and the total number of flowers in the canopy area of the tree. To work out the number of flowers visited by a nectar forager, observations were made on five number of bees thrice a day (8-10 hr, 12-14 hr and 15 – 17 hr) consecutively for three days during the peak flowering periods.

2.2 Pollen estimation

The amount of pollen produced by the trees was estimated by observing the number of flowers visited by pollen foragers (n=10) in a single trip. A known number of returning pollen foragers (n=25) were captured at the hive entrance and subjected to cold shock for 5 minutes to anesthetize them [6].The pollen pellets were dislodged from the corbiculae of the honeybees with a camel-hair paintbrush, and the pollen pellets were weighed to estimate the amount of pollen collected by a bee in its single trip (Plate 4).

To estimate the pollen produced by a single flower, pollen foraging bee on a tree was followed, and the number of the flowers visited by the bee until it disappeared/departed from the tree was recorded. Based on the estimated mean value of pollen load that a single bee can carry and the number of flowers the bee visited to acquire that much of pollen, the pollen production per flower was worked out as follows,

$$\textbf{Pollen produced per flower (mg)} = \frac{\textit{Mean value of pollen load a forager can carry (mg)}}{\textit{The no.of flowers visited by the forager in a single trip}}$$



a) *Persea americana*

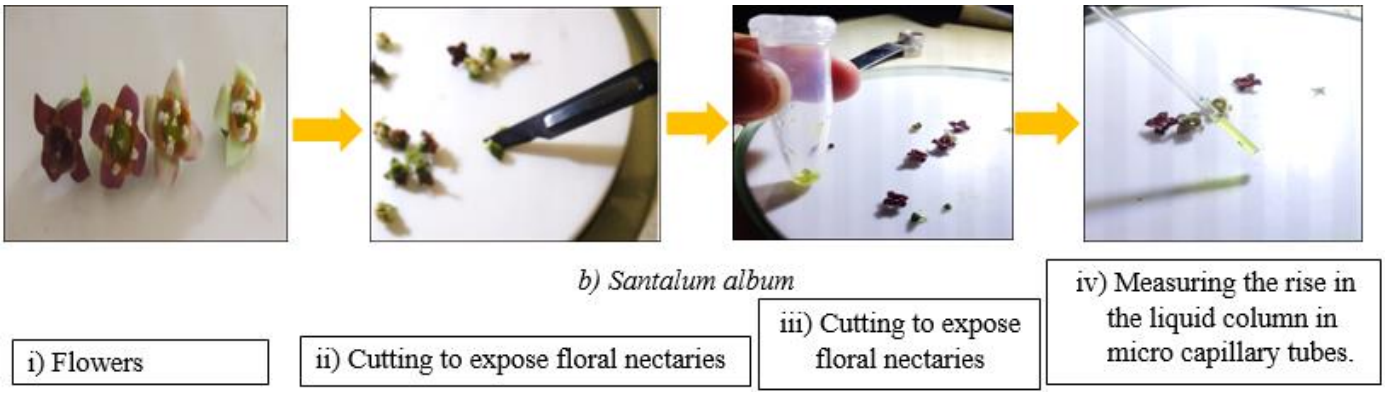


Plate 1: Stages in nectar washing technique

a) *Millettiapinnata* b) *Gliricidiasepium* c) *Cinnamomumzeylanicum*

Plate 2: Direct micro capillary tube technique

The visitation by the pollen foragers was also recorded thrice a day (8-10 hr, 12-14 hr and 15 –17 hr) for three days. The crop capacity and pollen carrying capacity of bees was used for estimating nectar and pollen produced per flower based on the fact that no forager bee returns to the hive until is honey stomach or corbiculae is completely filled during foraging trip.

2.3 Counting the number of inflorescences in a tree and flowers in an inflorescence

In bee forage species of *Cinnamomum zeylanicum*, *Santalum album*, *Persea americana* has panicle inflorescence and *Millettia pinnata*, *Gliricidiasepium* had raceme inflorescences that are arranged on the surface of the tree crown and also grouped; therefore, all groups within a given area were counted (1 m^2), and the results were extrapolated to the total estimated surface area of the tree crown. Around 20 inflorescences scattered throughout the tree were selected, and the number of flowers per inflorescence was ascertained [5].

2.4 Estimation of the crown surface area.

The total crown surface area of the forager tree species was calculated by measuring the basic data of the crown length, width, and then applying appropriate formulae, depending on the shape of the plant crown.

The length of the crown was measured by using the Electronic Hypsometer (Nikon Forestry Pro Laser range finder). The crown width was estimated by measuring the projection area of the crown diagonally on the ground using the measuring tape. The following formulae were used to calculate the crown surface area.

a. For trees with conoid crown shape surface area

$$Ca = \frac{\pi D}{2}\sqrt{L^2 + (\frac{D}{2})^2}$$

b. For trees with hemisphere crown shape surface area:

$$Ca = \frac{\pi D^2}{2}$$

Where

Ca = Crown surface area
L = Crown length
D = Crown width

a) Feeding station b) Sugar syrup on glass sides c) Foragers engorging the sugar syrup

Plate 3: Estimation of crop capacity of *Apisceranaindica*

a) Pollen trap laid at hive entrance b) Capturing of pollen foragers at the hive entrance

c) Captured pollen foragers d) Weighing of pollen pellets

Plate 4: Estimation of pollen load carried by a forager

The forage tree species *C. zeylanicum, P. americana, M. pinnata, G. sepium,* possessed hemisphere crown shape, and *S. album* had the conoidal crown shape during the observation.

2.5 Data analysis

The floral nectar and pollen production per floral unit between the selected bee forage tree was comparatively analyzed using one- way analysis of variance (ANOVA) and results are presented
as the mean values ± SD (standard deviation). The level of statistical significance required to measure differences between the means for all analyses was P = 0.05.

3. Results and Discussion

3.1 Nectar production

As a prerequisite to indirectly estimate the number of nectar foragers enticed by the flowers present in the tree canopy, the crop capacity of honeybees (*A. cerana*indica Fabr.) or the volume of honey stomach of them was determined.When 200 µl of sugar syrup (1:1: sugar: water) was offered to the five number of foraging bees, they together took up 136.14 ± 31.65 µl of the syrup ranging from 92 to 160.2 µl. The average quantity of the syrup engorged per bee recorded a mean value of 27.24 ± 6.35µl with a range of 17.12 to 32.04 µl. The mean value of 27.24 µl was considered the crop capacity (or volume of the honey stomach) of the *A.cerana indica* nectar foragers (Table 1).

There was a significant variation in the nectar produced per flower in different bee forage tree species. It was highest (3 µl/flower) in *Santalum album*, followed *M. pinnata* (0.95 µl/ flower), *G.sepium* (0.82 µl/flower); *C.zeylanicum* (0.52 µl/flower) and *P.americana* (0.53 µl/ flower). Earlier studies on different species of crop plants for nectar production potential showed variations from plant species to species. It was 2.85 µl per flower in cultivated *Vacciniumasheri* [7], 0.445 µl per flower per day in *Ocimum basilicum* [8], 0.1 to 3.8 µl per flower in *Allium ursinum* [9], 340 µl per flower in *Mucunajapira*and 310 µl per flower in *M. urens* [10]. These findings strongly imply that the nectar production potential is unique to each of the species and even the same species may produce different quantity of nectar in different geographic locations, as evident by the comparison of the quantity of nectar in *G. sepium* in the present investigation (0.82 µl/flower) to that of study from Vishakapatnam, which recorded 3-4 µl of nectar per flower [11] (Table 2).The number of flowers per square meter area of the tree canopy varied from the highest of 924 in *M.pinnata,* followed by 792 in *S. album*, 558 in *G. sepium*, 540 in *C. zeylanicum* and the lowest of103 in *P. americana* (Table 2). In a similar study [4], the number of flowers per unit volume of the canopy and also the number of flowers per plant was estimated (depending on feasibility, for tree species number of flowers per $m^3$of the tree canopy and in case of herbs, number of flowers per plant). According to that, the total number of flowers per m^3 of the tree canopy in different *Acacia* species (*A. asak, A. johnwoodii, A. ehernbergiana, A. tortilis, A. ethbaica, A. oerfata, A. gerrardii*) ranged from 2902 to 11,560; in *Ziziphus nummularia* and *Ziziphus spina-christi,* it was 57,420 and 43,000 per m^3 of the canopy, respectively. In case of herbs, *Lavandula dentate, L. pubescens, Nepetadeflersiana* and *Otostegia fruticosa,* the number of flowers per plant was 18,537, 17,750, 56,099 and 27,939, respectively A comparison of these results with the present findings indicates that the number of flowers produced is unique for each species of trees and plants as there may be variations in the number of flowers in relation to their size. When flowers are of smaller size, there may be more number of flowers per tree or plant.

The total canopy area of the forage species under this investigation was 70.68, 36.85, 19.35, 14.11 and 9.26 m^2 in *C. zeylanicum, P. americana, S. album, M.pinnata* and *G. sepium,* respectively (Table 2). These results are comparable with the average canopy surface area of *Ziziphus* tree as 87.5 m^2 with a range of 52.9 to 125.4 m^2[12] and for *Z. nummularia*, 45 ± 8 m^2[13].

The extrapolated data on the total number of flowers per tree in the present study recorded 38,167, 15,325, 13,037, 5167, and 3796 flowers in *C. zeylanicum, S. album, M. pinnata, G. sepium* and *P. americana,* respectively. The estimated nectar production per m^2 of the canopy area was 2376, 878.72, 462.02, 240.80 and 55.41 µl in *S. album, M. pinnata, G. sepium, C. zeylanicum,* and *P. americana,* respectively. However, the total amount of the nectar produced from the entire tree as per estimates was highest in *S. album* (45,975 µl) followed by *C. zeylanicum* (19,846.84 µl),*M.pinnata* (12,399.14 µl), *G. sepium* (4,278.28µl) and *P. Americana* (2,042.25 µl) (Table 2). The honey production potential of *Ziziphus spina-christi,* was estimated in earlier studies which recorded more numbers of small flower per tree and the average number of cymes per m^2 of canopy surface was 18,733.2. The average number of flowers per m^2 of the canopy surface was 43083.6. The average canopy surface of the tree was 87.5 m^2. Based on these data, it can be concluded

that a single tree can yield 3.6 kg of honey in one flowering season. When this 3.6 kg of honey was converted into its original form of nectar (by converting with the mean total sugar concentrations of 36 per cent in nectar), it works out to be 8.2 liters of nectar per tree per season [12].

Table 1: Particulars in estimation of crop capacity (honey stomach capacity) of nectar foragers of *Apiscerana indica* Fab.

Slide No.	Quantity of sugar syrup			
	Provided (µl)	Left out (µl)	Engorged by	
			Five bees (µl)	Single bee (µl)
1	200	39.8	160.2	32.04
2	200	41	159	31.8
3	200	40.1	159.9	31.98
4	200	39.9	160.1	32.2
5	200	79.9	120.1	24.02
6	200	114.4	85.6	17.12
7	200	107.98	92	18.4
8	200	40	160	32
9	200	41.4	158.9	31.78
10	200	94.4	105.6	21.12
Mean	-	63.88± 31.63	136.14 ± 31.65	27.24 ± 6.35

Table 2: Nectar production potentiality of important bee forage trees at College of Forestry campus, Ponnampet.

Bee forage trees	Mean quantity nectar / flower (µl)	No. of flowers / m^2	Total canopy area (m^2)	Average number of flowers /tree	Estimated nectar production (µl)		No. of nectar foragers enticed	
					Per m^2 of the canopy	Per tree	Per m^2 of the canopy	Per tree
Cinnamomum zeylanicum	0.52[c]	540	70.68	38,167	240.80	19,846.84	9	729
Persea americana	0.53[c]	103	36.85	3,796	55.41	2,042.25	2	75
Gliricidiasepium	0.82[b]	558	9.26	5,167	462.02	4,278.28	17	157
Millettia pinnata	0.95[b]	924	14.11	13,037	878.72	12,399.14	32	455
Santalum album	3.00[a]	792	19.35	15,325	2376	45,975.00	87	1688
SE m(±)	0.065							
CD (0.05)	0.192							

Figures with similar letters as superscript do not differ significantly, CD-Critical Difference

A similar estimate in mustards indicated that a one- hectare area of *Brassica juncea*(brown mustard) and *Sinafisalba* (white mustard) could produce 65.5 and 7.12 kg of nectar sugar, respectively [14]. Comparison of the results in the present investigation and that of the earlier findings indicated that the amount of nectar produced per tree per plant depends on the number of flowers per unit area or volume of the canopy of the plant.

Among the selected bee forage trees for the study, *S.album* enticed the highest (87) number of *A.cerana indica* nectar foragers, followed by *M. pinnata* that sufficed 32 nectar foragers. The nectar produced per meter square of the canopy in *G.sepium, P. americana* was sufficient for 17 and nine nectar foragers, respectively. However, the lowest (2) number of nectar foragers was found to be enticed in per square meter of the canopy of *P.americana* (Table 2).

Estimates on the potentiality of the entire tree to entice the nectar foragers, indicated that the highest (1688) number of *A.cerana indica* bees were enticed by *S. album*, followed by *C. zeylanicum* (729 bees). The lowest number of (75) nectar foragers was enticed by *P.americana*while *M. pinnata* and *G.sepium* enticed 455 and 157 foragers, respectively (Table 2). There was no direct relationship between the number of foragers enticed by flowers present in one m^2 area of the canopy and the entire canopy of the same species of the trees. This is because, though some species bore more flowers per meter square area of the canopy, their total canopy area was less. The total canopy area being a parameter associated and varies with the age and growth of the tree species.

3.2 Pollen production

The mean quantity of pollen production per flower varied significantly among the different selected bee forage trees. The amount of pollen per flower (3.92 mg) in *G.sepium* was significantly high compared to other species. *Persea americana* produced the next highest amount of pollen per flower (1.77 mg), while the lowest amount of pollen per flower (0.33 mg) was recorded in *C. zeylanicum.* In *S. album* and *M. pinnata*, the pollen production was 1.27mg and 0.87 mg per flower, respectively. These two species stood on par with *P.americana* and *C. zeylanicum*in pollen production per flower (Table 3). This significant difference in amounts of pollen rewards produced may be due to the inherent efficiency of floral units of the assessed tree species as they are morphologically different from each other. In a similar study, in Poland the pollen output from *Syringaobata var. dilatate* and *S. meyeri*' Palibin' was estimated.It ranged from 9.6 – 29.1 mg per inflorescence (115 flowers) in the former and 9.6–28.5 mg per inflorescence (138 flowers) in the latter species. The variation may be due to the differences in the efficiency of inherent tissues producing pollen [15]. The estimated pollen production per m^2 of the canopy and in the entire canopy (per tree) was highest in *G. sepium* (2187.3mg and 20,254.6 mg) followed by *S. album (*1005.8 mg and 19,462.75 mg), *M.pinnata*(803.8 mg and 11,342.1 mg) and *P. Americana* (182.3 mg and 6718.9 mg). *Cinnamomum zeylanicum* recorded the lowest quantity of pollen (167.4 mg and 11,984 mg) (Table 3). While estimating the pollen production in *Syringaoblata* and *Syringameyeri*, an output of

pollen ranging from 0.9 kg to 8.1 kg per shrub was recorded [15]. In the present investigation also the abundance of flowers in bloom and the abundance of flowers per unit area of the tree canopy varied and recorded a difference in estimated pollen output.

Based on the total pollen production per tree, it was evident that *G. sepium* enticed the maximum (1178) number of pollen foragers of *A. cerana indica* while *S. album* enticed, 1,132 foragers. A minimum number of pollen foragers (391) was, however, sufficed by *P. americana* while *C. zeylanicumn* and *M. pinnata* enticed 698 and 659 pollen foragers, respectively (Table 3). In the present investigation, the pollen foragers enticed by flowers present in per m^2 and per tree were maximum for *G. sepium* (127 and 1178) followed by *S. album* (58 and 1132), *M. pinnata* (47 and 659) and *C. zeylanicum* (10 and 698) while *P. americana* enticed the least (11 and 391) pollen foragers. It was evident that although *C. zeylanicum* sufficed the least number of pollen foragers per m^2 of the canopy when extrapolated to the whole tree, the number of bees could suffice from the pollen produced were relatively high (Table 3). For *Ziziphus nummularia*, the observation on foraging activity of *A. melliferajementica* pollen foragers resulted in 1.9 ± 0.80 workers foraging on 200 flowers [13].

Table 3: Pollen production potentiality of in important bee forage trees at the College of Forestry campus, Ponnampet.

Bee forage trees	Mean quantity pollen/ flower (mg)	No. of flowers / m^2	Total canopy area (m^2)	Average number of flowers /tree	Estimated pollen production (mg)		No. of pollen foragers enticed	
					Per m^2 of the canopy	Total production /tree	Per m^2 of the canopy	Per tree
Cinnamomum zeylanicum	0.33^{c}	540	70.68	38,167	167.4	11,984	10	698
Persea americana	1.77^{b}	103	36.85	3,796	182.3	6718.9	11	391
Gliricidiasepium	3.92^{a}	558	9.26	5,167	2187.3	20,254.6	127	1178
Millettia pinnata	0.87^{bc}	924	14.11	13,037	803.8	11,342.1	47	659
Santalum album	1.27^{bc}	792	19.35	15,325	1005.8	19462.75	58	1,132
SE m(±)	0.087							
CD (0.05)	1.231							

Figures with similar letters as superscript do not differ significantly, CD-Critical Difference

4. Conclusion

A close perusal of the findings of the present investigation lead to a conclusion that the bee forage value or the inherent capacity of plants to produce pollen and nectar varies from species to species and also within the same species depending on the climatic and edaphic factors. Among the species assessed for their bee forage value, *S. album* emerged as the most potential nectar producing tree, while *G. sepium* was the most potential pollen-producing tree. Thus, these species with maximum forage value can be augmented in resource dearth areas apart from conserving the existing ones.

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